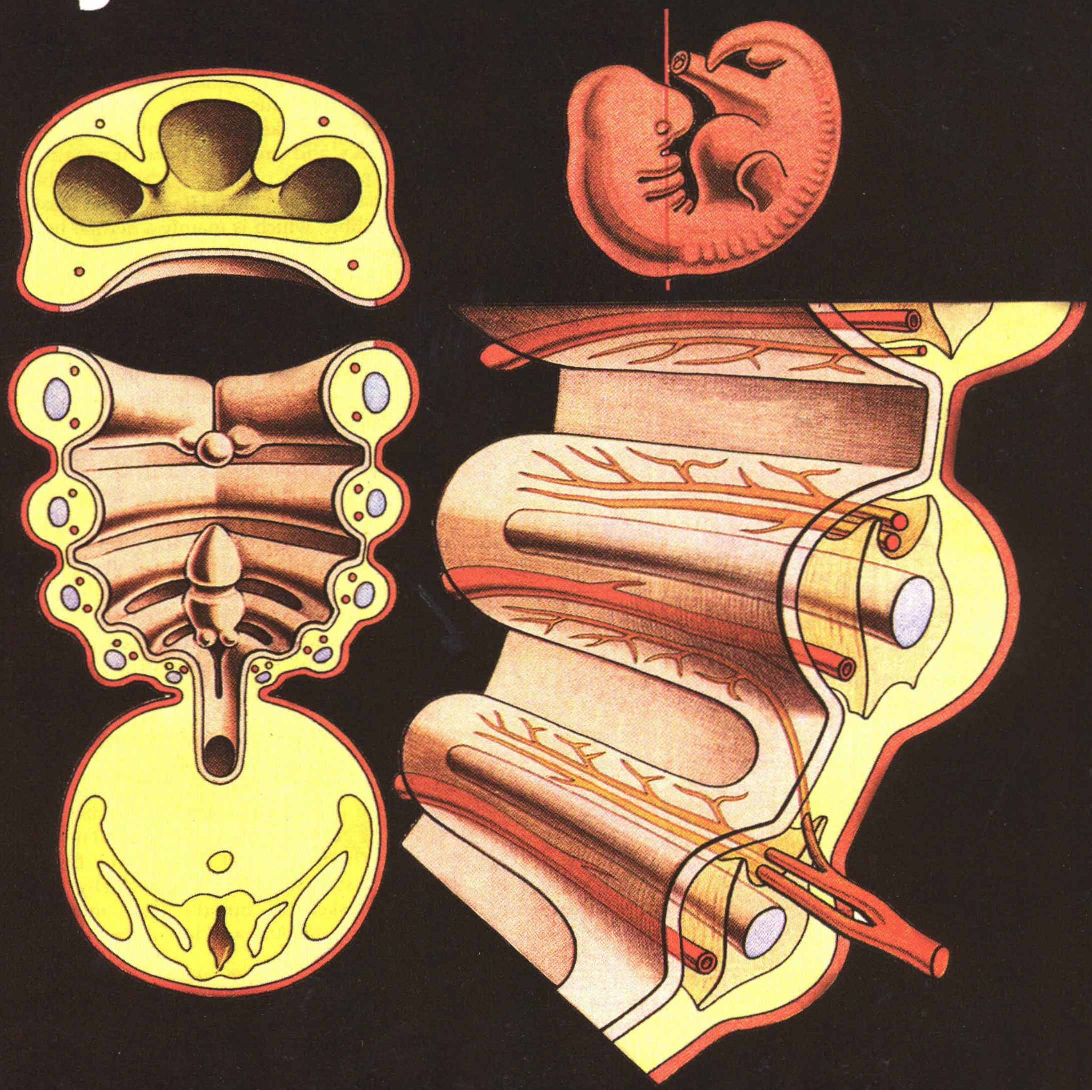
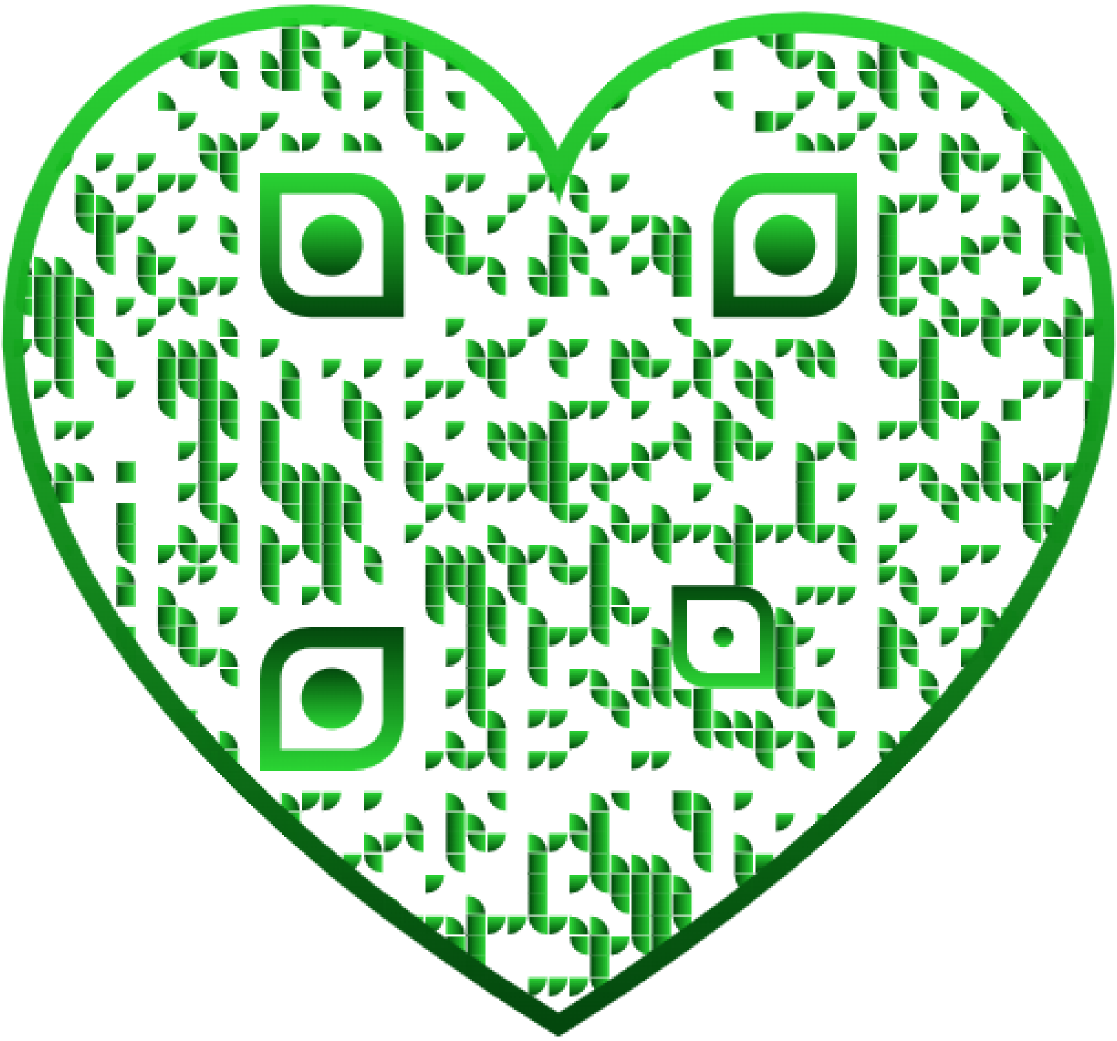
HUMAN
ANATOMY

IHAB

Special Embryology
Is easy
to study





Index

Chapter 1: Pharyngeal apparatus & pharyngeal gut

Page

- Pharyngeal arches........1
- Pharyngeal clefts & pouches........2
- Development of the face........3
- Development of the palate........4
- Development of the tongue........5
- Development of the thyroid........6
- Development of respiratory system........7

Chapter 2: Development of digestive system

- Development of esophagus & stomach........9
- Development of duodenum & pancreas........10
- Development of liver & gall bladder........11
- Development of midgut........12
- Development of hindgut........13

Chapter 3: Development of urinary system

- Development of kidney & ureter........15
- Development of cloaca........17
- Development of urinary bladder........18
- Development of urethra........19

Chapter 4: Development of genital system

- Development of gonads & testis........20
- Development of ovary........22
- Development of genital ducts........23
- Development of external genitalia........24

Chapter 5: Development of cardiovascular system

- Development of heart, sinus venosus........26
- Development of atria........27
- Development of ventricles........29
- Development of bulbus cordis........30
- Development of cardiac valves........31
- Development of primitive aortae & dorsal aorta........32
- Development of aortic arches........34
- Fetal circulation........36

Chapter 6: Endocrine glands, muscles & diaphragm

- Development of endocrine glands........38
- Development of muscles........39
- Development of diaphragm........40

Chapter 7: Skull, Vertebral column, limbs & skin

- Development of skull........41
- Development of vertebral column & limbs........42
- Development of skin & mammary gland........44

Chapter 8: spinal cord........46

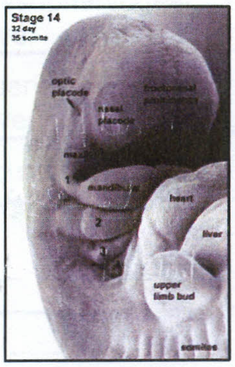
- اللهم افتح عليّ فتوح العارفين ... ♥

wall of pharynx ← اسطوانة من ٣ طبقات

ectoderm ، mesoderm ، endoderm عملها

Pharyngeal (branchial) apparatus

شبه هنا شكل السمك gills of fish (branchia)


Stage 14
32 day
35 somite
optic placode
frontonasal prominence
nasal placode
maxilla
1
mandibular
2
3
heart
liver
upper limb bud
somites

- The pharyngeal arches contribute the characteristic external appearance of the head and neck of the embryo
- These arches appear in 4th and 5th week of development.
- There are 6 pharyngeal arches. They are separated from each other:
  - Externally by 4 ectodermal clefts (grooves) and
  - Internally by 5 endodermal pouches.

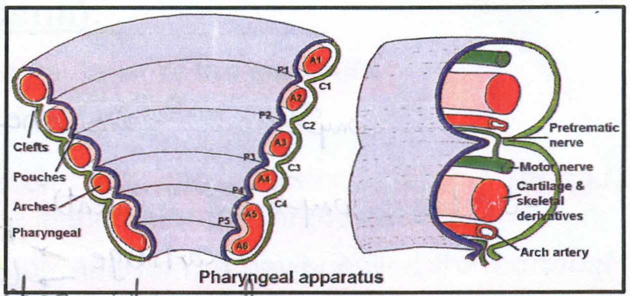
Pharyngeal arches

بتتكون أثناء الـ folding

تلف حوالين الـ Pharynx

Definition:

(٦ يمين و ٦ شمال)


A1
A2
A3
A4
A5
A6
P1
P2
P3
P4
P5
C1
C2
C3
C4
Clefts
Pouches
Arches
Pharyngeal
Pretrematic nerve
Motor nerve
Cartilage & skeletal derivatives
Arch artery

Pharyngeal apparatus

- Pharyngeal arches are 6 curved cylindrical mesenchymal thickenings on each side of the pharyngeal gut.

mesodermal

كل cylinder عبارة عن mesoderm, بتعمل grooves بين الـ arches

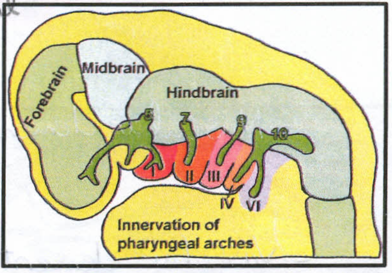
- Each pharyngeal arch consists of a core of mesenchymal tissue covered on the outside by surface ectoderm and on the inside by endoderm of the pharyngeal gut.

6 arches + 4 clefts + 5 pouches = pharyngeal apparatus

- Each arch has its own arterial component and nerve component.

Time of appearance:

d ↘ كل arch له dorsal end ، ventral end

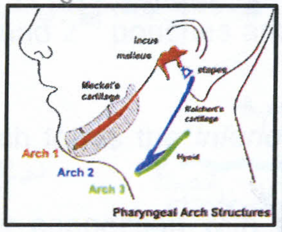

Forebrain
Midbrain
Hindbrain
5
7
9
10
I
II
III
IV
VI

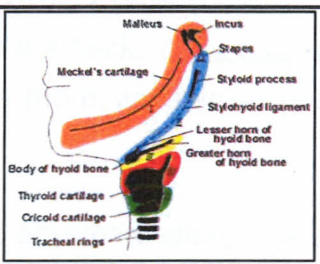
Innervation of pharyngeal arches

- These arches appear in the fourth and fifth weeks of development.
- Cranial arches precede the caudal ones and are more prominent.

ما عدا الـ 1st arch عنده شبه الـ U shaped C (2 ventral ends) علشان يعمل الـ face

Fate: 1- Derivatives of pharyngeal arches (mesoderm):

Arch	Skeletal derivatives	Muscular derivatives	Nerve 5 7 9 10
1st arch (mandibular arch): consists of maxillary and mandibular processes	Dorsal end **Mesenchyme of maxillary process** gives maxilla, zygomatic & part of temporal bones. (membranous assification) no cartilage here ventral end of the arch **Mandibular process, which contains Meckel's cartilage:** cartilagenous assification 1- Malleus. 2. Incus. 3- Sphenomandibular ligament. 4- Anterior ligament of malleus.  incus malleus stapes Meckel's cartilage Reichert's cartilage hyoid Arch 1 Arch 2 Arch 3 Pharyngeal Arch Structures N.B.: Mandible is formed by membranous ossification around Meckel's cartilage.	**(A) 4 muscles of mastication:** - Temporalis, masseter. - Medial & lateral pterygoids. **(B) 4 other muscles:** - Mylohyoid & anterior belly of digastric. - Tensor palati and tensor tympani. طلع من الـ 2nd arch ، ودخل في الـ arch اللي قبله	- Mandibular nerve. of trigeminal - Maxillary nerve. - Chorda tympani (pretrematic nerve of the 1st arch). Pre → infront treme → Cleft branch 1st arch
2nd arch (hyoid arch)	**Reichert's cartilage:** differentiates into: - Stapes, styloid process. assi. - Stylohyoid ligament. - Lesser horn and upper part of body of hyoid bone.	- Muscles of scalp and face, platysma. - Stylohyoid muscle. - Posterior belly of digastrics. - Stapedius muscle.	Facial nerve

3rd arch	Greater horn and lower part of body of hyoid bone.	Stylopharyngeus.	Glossopharyngeal nerve.
4th arch	Laryngeal cartilages. thyroid, Cricoid, ... 	- Cricothyroid. - Levator palati. كل الـ ms of Palate tenso palati: - Constrictors of pharynx. - Intrinsic muscles of larynx.	Superior laryngeal nerve. of Vagus
6th arch			Recurrent laryngeal nerve.

Malleus
Incus
Stapes
Meckel's cartilage
Styloid process
Stylohyoid ligament
Lesser horn of hyoid bone
Greater horn of hyoid bone
Body of hyoid bone
Thyroid cartilage
Cricoid cartilage
Tracheal rings

N.B.: the 5th arch either never forms in human or forms and rapidly regresses.

2- Derivatives of the pharyngeal clefts (ectoderm):

1st cleft: Forms the external auditory meatus and the outer layer of the ear drum.

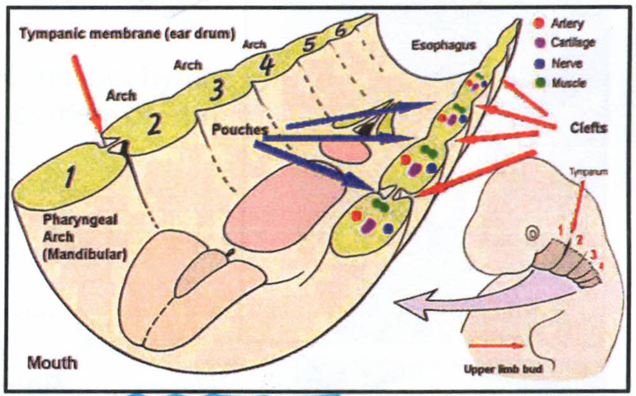
⇒ فيها فراغ في الـ neck

2nd, 3rd and 4th clefts:

- Active proliferation of mesenchymal tissue of the second arch causes it to overlap the 3rd and 4th arches. Finally, it merges with the epicardial ridge in the lower part of the neck. Pericardium
- The 2nd, 3rd and 4th cleft lose contact with the outside and form a cavity called the ***cervical sinus*** which later on disappears (obliterates) and does not give rise to any structure.

3- Derivatives of the pharyngeal pouches (endoderm):

Each pouch is divided into dorsal & ventral wings. مش 8؛ زي ما اتقالنا


Tympanic membrane (ear drum)
Arch
Arch
Arch
1
2
3
4
5
6
Pouches
Esophagus
Artery
Cartilage
Nerve
Muscle
Clefts
Tympanum
1
2
3
4
Pharyngeal Arch (Mandibular)
Mouth
Upper limb bud

1st pouch:

It forms *tubotympanic recess* which gives rise to:

- Eustachian tube.
- Middle ear cavity. (tympanic cavity)
- Mastoid antrum. متصل بالـ middle ear
- Inner layer of the ear drum.

2nd pouch:

The epithelial lining of the second pharyngeal pouch proliferates and forms buds. براعم

The buds are invaded by mesodermal tissue, forming the the palatine tonsil. (lymphoid tissue is mesodermal in origin)

N.B. the ventral parts of the 1st and 2nd pouches are obliterated by the developing tongue.

3rd pouch:

The dorsal wing of the 3rd pouch forms the *inferior parathyroid gland,* (thyroid بدال) while the ventral wing forms the *thymus gland.* (Sternum ورا الـ)

final distination

Both gland primordia lose their connection with the pharyngeal wall and then the thymus migrates pulling the inferior parathyroid gland with it.

4th pouch:

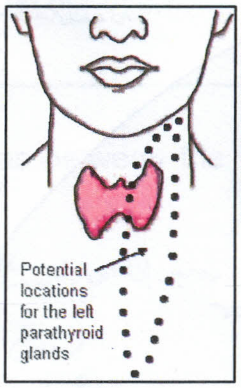
The dorsal wing of the 4th pouch forms the *superior parathyroid gland.*

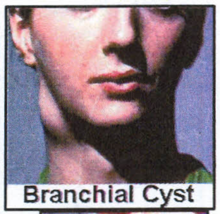
5th pouch:

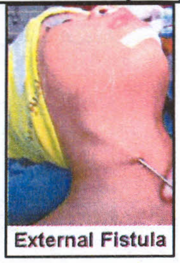
It gives rise to the ultimobranchial body, which is later incorporated into thyroid gland.

The ultimobranchial body gives rise to the parafollicular (C) cells of the thyroid gland.

Birth Defects involving the pharyngeal Region:


Potential locations for the left parathyroid glands


Branchial Cyst


External Fistula

1- Ectopic thymic and parathyroid tissue:
خارج مكانه الأساسي

- The thymus may remain in the neck. (Accessory thymic tissue)

The inferior parathyroid is more variable in position than the superior one.

2- Branchial cyst: كيس

It is a cystic swelling lying anywhere along the anterior border of sternomastoid. Side of neck

→ It results from failure of obliteration of the cervical sinus.

3- External cervical fistula: the branchial cyst opens externally into the skin.

4- Internal branchial fistula: the branchial cyst opens internally into the pharynx.

تأسيس

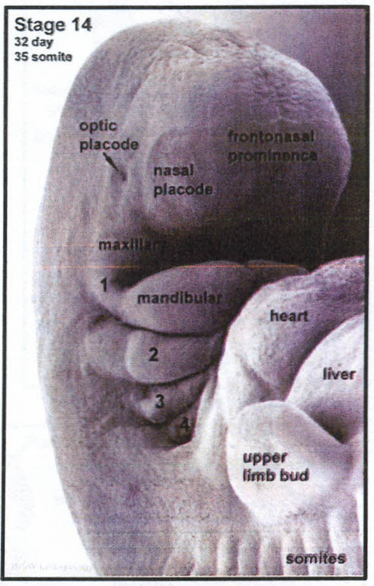
Development of the Face

Cavities nasal, oral (buccal) هيكل bulges forebrain, Pericardial منخفض بين الـ depression

Formation of 5 prominences around the stomodeum

• buccoph. memb + pharynx + ال بيغطيه, ectoderm مغطى ب

The 1st pharyngeal arch develops 2 prominences:


Stage 14
32 day
35 somite
optic placode
nasal placode
frontonasal prominence
maxillary
1
mandibular
2
3
4
heart
liver
upper limb bud
somites

② * Maxillary prominences, which can be distinguished lateral to the stomodeum.

② * Mandibular prominences, which can be distinguished caudal to the stomodeum.

= process

The frontonasal prominence is formed by proliferation of mesenchyme ventral to the brain vesicles. It constitutes upper border of the stomodeum. forebrain forebrain bulge هيكبر وينزل للتحت down ward growth

So the stomodeum becomes surrounded by 5 prominences:

Frontonasal prominence lies cranially.

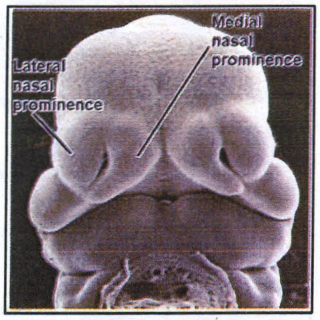
2 maxillary prominences lie on each side and cranially.

2 mandibular prominences lie caudally.

frontonasal
max ○ max
Stomodeum
mand mand

Differentiation and fusion of the 5 prominences:

either complete or partial → Anomaly

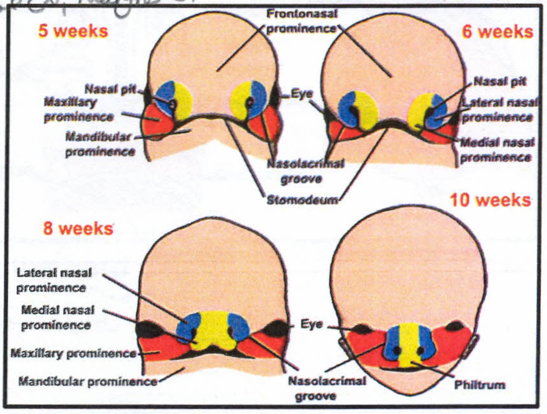

Lateral nasal prominence
Medial nasal prominence

a) The fronto-nasal prominence

The 2 Nasal placodes develop on both sides of the fronto-nasal prominence. inferolateral parts ectodermal thickenings (meso derm)

The nasal placodes become invaginated to form nasal pits (olfactory pits). حفرة Each pit is surrounded by lateral and medial nasal prominences.

ال margins بتاعة ال pit بتتكون نتيجة لزيادة حول الحفرة.


5 weeks
6 weeks
Frontonasal prominence
Nasal pit
Maxillary prominence
Mandibular prominence
Eye
Nasolacrimal groove
Stomodeum
Nasal pit
Lateral nasal prominence
Medial nasal prominence
8 weeks
10 weeks
Lateral nasal prominence
Medial nasal prominence
Maxillary prominence
Mandibular prominence
Eye
Nasolacrimal groove
Philtrum

The maxillary prominences grow medially, compressing the medial nasal prominences toward midline.

The two medial nasal prominences merge together and the cleft between the medial nasal prominence and the maxillary prominence is lost.

الـ eye كانت في الجنب وبدأت تلف معاهم لقدام

Fate:

The fronto-nasal prominence forms forehead الجبهة and bridge of nose. الجزء الفوقاني

Frontal (intermaxillary segment) + 2 maxillary processes [illegible] + tip [illegible]

The medial nasal prominence forms philtrum of upper lip, crest and tip of nose.

The lateral nasal prominence forms ala of the nose.

Intermaxillary segment medial nasal prominence نازلة، وجاية من +

It is the free terminal part of the frontonasal prominence which lies between the tips of the 2 maxillary prominences. extension from fused medial prominences.

Derivatives:

- A labial component, which forms the philtrum (depression) of the upper lip. → face [illegible]
- An upper jaw component (→ median part), which carries the four incisor teeth (2 central, 2 lateral). Jaw
- A palatal component, which forms the triangular primary (primitive) palate. Palate

b) The 2 maxillary prominences

fuse e' frontal prominence, eye [illegible] mandibular process, medial, lateral nasal prominences

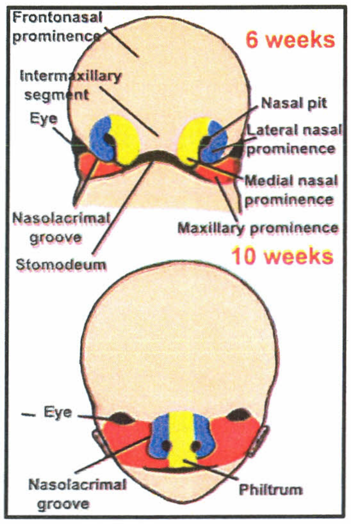
They give rise to:

a) Part of cheek. خد

b) The upper lip (except the philtrum).

c) The upper jaw (except the median part carrying the 4 incisors).

d) The 2^{ry} palate.


Frontonasal prominence
6 weeks
Intermaxillary segment
Eye
Nasal pit
Lateral nasal prominence
Medial nasal prominence
Nasolacrimal groove
Maxillary prominence
Stomodeum
10 weeks
Eye
Nasolacrimal groove
Philtrum

c) The 2 mandibular prominences

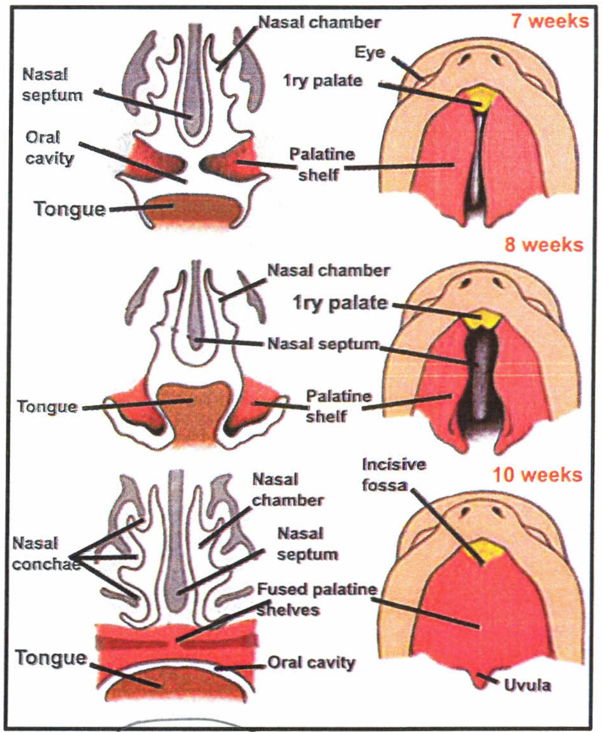
They fuse above with the maxillary prominences forming most of cheek. chin

They fuse with each other medially (at midline) forming the lower lip and jaw. → philtrum مفيش xi) tip

oral & nasal cavity [illegible]

Development of the Palate

The palate is formed of 2 components: 1^{ry} and 2^{ry} palates.


Nasal chamber
7 weeks
Eye
1ry palate
Nasal septum
Oral cavity
Palatine shelf
Tongue
8 weeks
Nasal chamber
1ry palate
Nasal septum
Palatine shelf
Tongue
Incisive fossa
10 weeks
Nasal chamber
Nasal septum
Nasal conchae
Fused palatine shelves
Tongue
Oral cavity
Uvula

i) The primary palate

It is the small anterior triangular part of the palate which carries the incisive fossa.

It develops from the intermaxillary segment of the frontonasal prominence.

ii) The secondary palate

It is the remaining large part of the palate.

It is formed by 2 palatine shelves (which arise from the maxillary prominences).

The 2 palatine shelves grow medially to fuse with each other and with the 1^{ry} palate anteriorly.

بالعرض

The nasal Septum

2 nasal cavity + [illegible]

It descends vertically from the frontonasal prominence to fuse with the upper surface of the palate in the middle line. 2 secondary palates

Ossification occurs in the **anterior part of the palate** forming the hard palate.

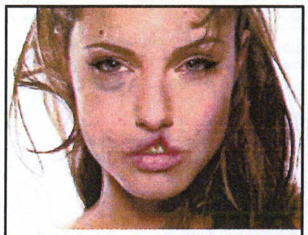
The **posterior part** remains fleshy and forms the soft palate. + uvula

Congenital anomalies of the face and palate

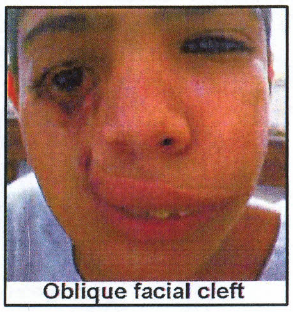
1- Oblique facial cleft:

There is a cleft lip which extends along the side of the nose. شق

It results from failure of fusion between maxillary prominence and lateral & medial nasal prominence.



Lateral cleft lip



Oblique facial cleft

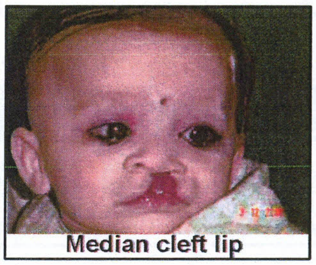
2- Cleft lip (hare-lip): الشفة الارنبية

Uni **Lateral cleft lip:**

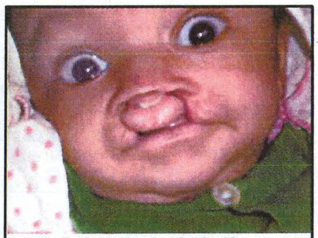
It is due to failure of fusion between the maxillary prominence and the medial nasal prominence on one side only.

Bilateral cleft lip:

It is due failure of fusion between the maxillary prominence and the medial nasal prominence on both sides. intermax. Segment + بس لسه (philtrum) موجودة



Median cleft lip



Bilateral cleft lip

Median cleft lip

It is caused by incomplete fusion of the two medial nasal prominences in the midline i.e. the philtrum is absent.

3- Cleft palate:

It is due to failure of fusion between the different segments of the palate.

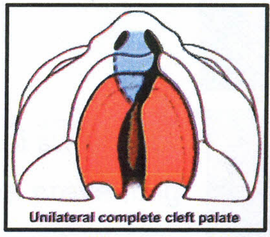
Types:

1) Unilateral complete cleft palate: A cleft runs between the 2 palatine shelves then between the pre-maxilla and one palatine process. الـ 2 2ry مالحموش سوا وواحد منهم مالحمش مع الـ 1ry

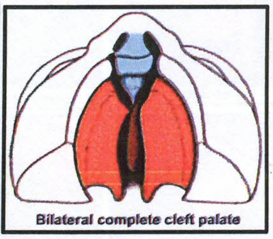
2) Bilateral complete cleft palate: the cleft runs between the 2 palatine processes. It extends anteriorly in a V shaped manner separating the pre-maxilla from the 2 palatine shelves. الـ 2 2ry مالحموش سوا ولا مع الـ 1ry

3) Partial cleft palate: may affect the soft palate alone or the posterior part of hard palate. الـ 2 2ry مالحموش سوا في الـ midline لكن لاحمين مع الـ 1ry عادي

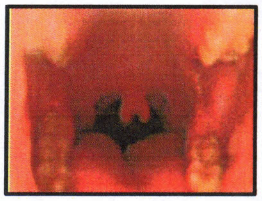
4) Cleft uvula: the cleft affects the uvula alone.

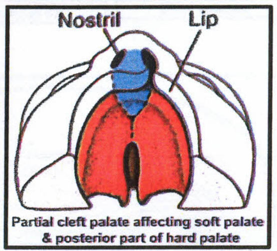


Unilateral complete cleft palate



Bilateral complete cleft palate





Partial cleft palate affecting soft palate & posterior part of hard palate

Derivatives of the floor of the pharyngeal gut

foregut (Cranial end)

= Ventral wall مبطن بإندودرم وكته من و برا غلاف الاكتودرم

Resp. System
thyroid g
tongue

embryo وضع جنب

1- Development of the tongue

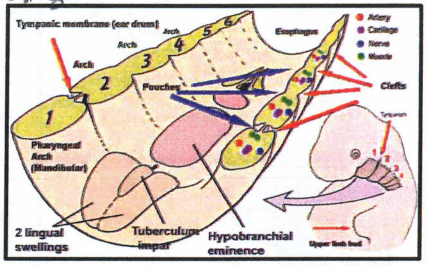
(I) Muscles of the tongue

- Most of the tongue muscles are derived from the 2nd 3rd and 4th occipital myotomes. (of occ. Somites) ex. muscles + دي hypoglossal معاها الـ [illegible]
- Some of the tongue muscles differentiate in situ. نفسه floor of pharynx + mesoderm حاجة من int. muscles

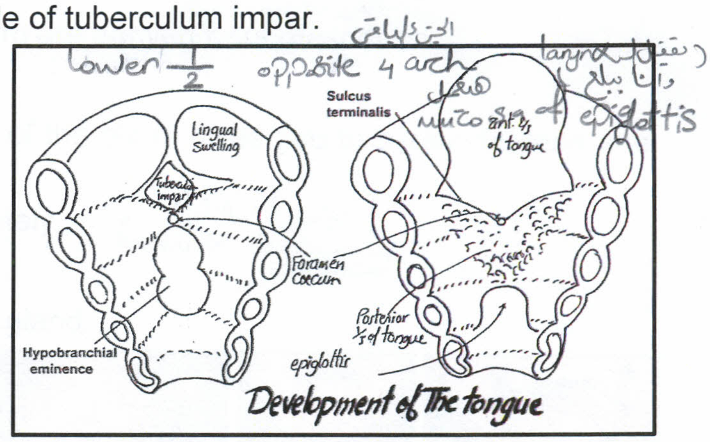
(II) Mucous membrane

Anterior ⅔: arises from 3 swellings derived from ventral part of 1st pharyngeal arch on both sides: (fuse)

Tuberculum impar: (single) a median elevation between the ventral ends of 1st pharyngeal arch.



Two lateral lingual swellings: one on either side of tuberculum impar.


الجزء الباقي
lower 1/2
opposite 4 arch
larynx بتقفل الـ
وانا ببلع
هيعمل
muco sa of epiglottis
Sulcus terminalis
Lingual Swelling
Tuberculum impar
ant. ⅔ of tongue
Foramen Caecum
Posterior ⅓ of tongue
Hypobranchial eminence
epiglottis

Development of The tongue

Posterior ⅓ of tongue: develops from the upper ½ of the **hypobranchial eminence**. 3, 4 arch
معظمه mainly جزء صغير

The posterior ⅓ fuses with anterior ⅔ along a V-shaped **sulcus terminalis**. apex posteriorly (foramen caecum)

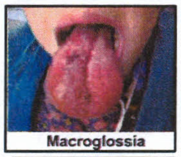
At first the tongue is fused with the floor of the pharyngeal gut. Later on **linguo-gingival groove** appears along the ventral and lateral side of the tongue freeing the tongue from the floor of the mouth. بس بردو هيفضل متعلق
tongue تحت
سور اللد
frenulum linguae بتاعه

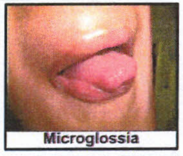
Nerve supply of the tongue:

The composite character of the tongue is indicated by its innervation.

Motor		Hypoglossal nerve (nerve of occipital myotomes).
Sensory	**Anterior ⅔:**	**General sensation:** lingual of mandibular (nerve of 1st arch).
		Taste sensation: Chorda tympani (pretrematic nerve of the 1st arch).
	Posterior ⅓:, على طول	**General and taste sensation:** ***Glossopharyngeal nerve*** (nerve of the 3rd arch). الى قبل الـ epigl. most Pos. Part ***Internal laryngeal*** of superior laryngeal nerve (nerve of the 4th arch).

Congenital anomalies of the tongue:


Macroglossia


Microglossia

1- **Microglossia:** is abnormally small-sized tongue.

2- **Macroglossia:** is abnormally large-sized tongue.

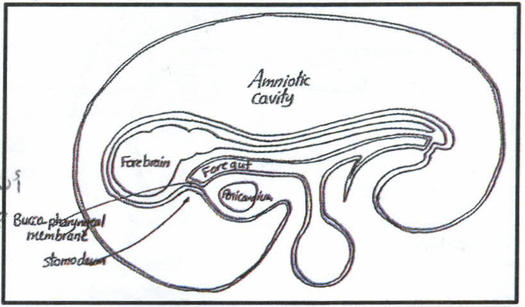
3- **Bifid tongue (rare):** due to failure of fusion of the 2 lingual swellings. من قدام

4- **Tongue tie:** the frenulum extends to the tip of the tongue preventing its protrusion. الـ groove مش عميق كفاية إنه
يحرر الـ tongue دماتتحلش عن مستخبي
لكن قدام لأ)

Tongue tie

Bifid tongue

2- Development of the thyroid gland

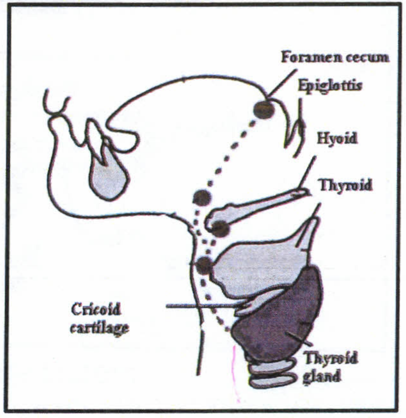

Amniotic cavity
Forebrain
Foregut
Pericardium
Bucco-pharyngeal membrane
stomodeum

Thyroid primordium appears as a median endodermal proliferation in floor of the pharynx between tuberculum impar and hypobranchial eminence. هتنزل تتوصل لـ قدام
ورا
تحتا الـ mesoderm

This site is indicated in adult tongue by the foramen caecum.

This thickening is invaginated to form a bilobed diverticulum which descends ventral to the developing hyoid bone then ventral to the developing larynx. أنبوبة صغيرة
متعمل 2lobes ف اجزاء

It remains connected to dorsum of the tongue by the thyroglossal duct.


Foramen cecum
Epiglottis
Hyoid
Thyroid
Cricoid cartilage
Thyroid gland

The thyroid gland reaches its position finally by 7th week.

N.B.:

The thyroid follicles are derived from endodermal cells of the thyroglossal duct. floor of pharynx حاجة من

The parafollicular (C) cells are derived from the ultimobranchial body. 5th branchial Pouch

اللى غاصت فيه

The inner true capsule and connective tissue septa are derived from mesoderm.

Fate of the thyroglossal duct:

The part of duct between hyoid bone and isthmus of the gland gives rise to pyramidal lobe and levator glandulae thyroideae. (not usually)

Above the hyoid bone the duct degenerates completely. till dorsum of tongue. ستيب مكانها foramen caecum (مسدودة)

Congenital anomalies:

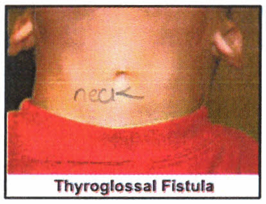
1) **Thyroid agensis:** Congenital absence of thyroid gland.

2) **Lingual thyroid:** The thyroid fails to descend and lies in the substance of the tongue.

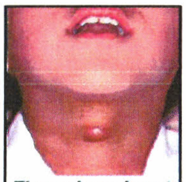
3) **Aberrant (retrosternal) thyroid:** The thyroid descends to reach thorax. نزلت اكتر من اللازم

4) **Thyroglossal cyst:** Due to persistence of a part of the thyroglossal duct unobliterated. front (midline) of neck.

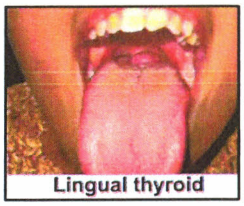
5) **Thyroglossal fistula:** Presence of a communication between thyroglossal cyst & skin of neck.



Thyroglossal Fistula



Thyroglossal cyst



Lingual thyroid

3- Development of the respiratory system

Naso pharynx, laryngeo pharynx, trachea, bronchial tree.

The epithelium develops from the endoderm of the foregut: a respiratory diverticulum appears as an outgrowth from the ventral wall of the foregut. opposite arches 4, 6 = floor (endoderm)

Two longitudinal endodermal ridges diverticulum [illegible] **(tracheoesophageal ridges)** develop on both sides separate the diverticulum from the foregut.

These ridges [illegible] **fuse** at midline **to form tracheoesophageal septum** dividing the upper part of foregut into: [illegible] مش للآخر [illegible] connected [illegible] (laryngeo pharynx +, laryngeal [illegible]

1. **Dorsal part** forms the esophagus. orifice [illegible]
2. **Ventral part** forms the laryngeo-tracheal tube. صغيرة

The laryngeo-tracheal tube grows caudally:

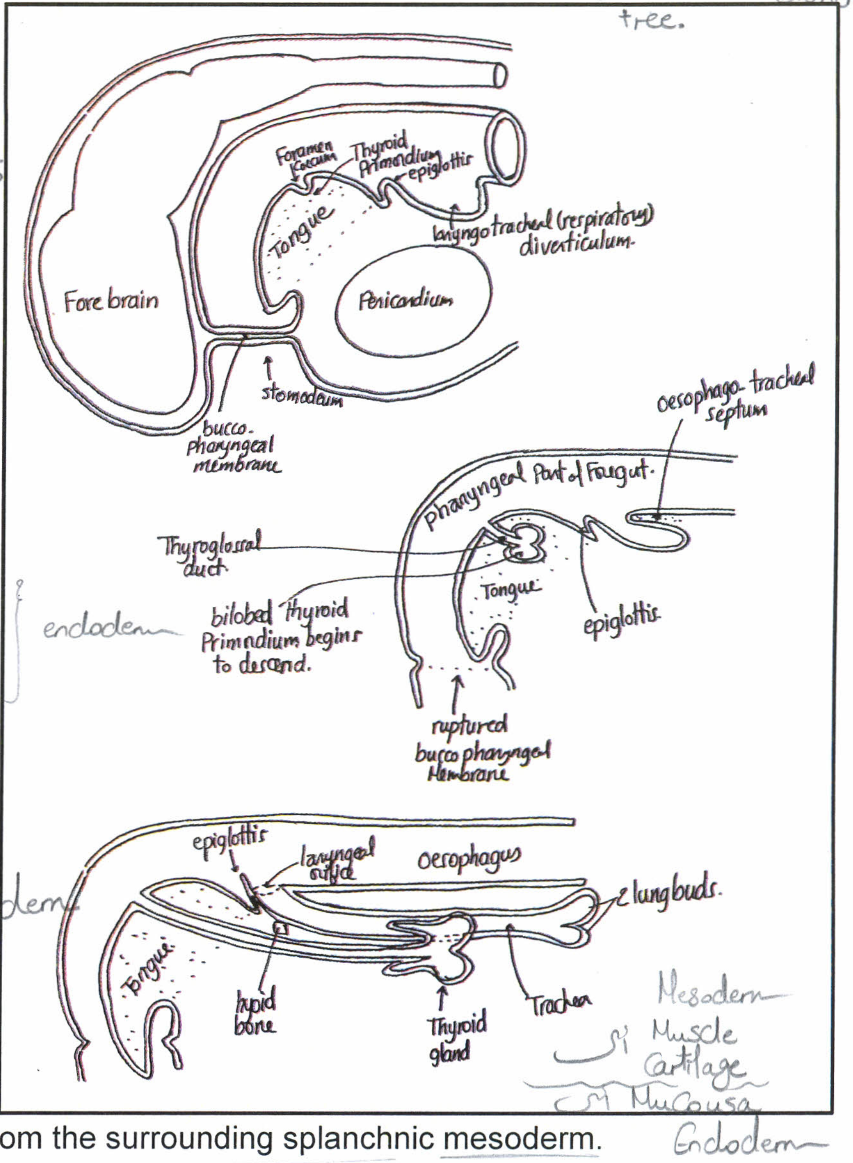
Its upper part forms the larynx. mucosa of

The next part forms trachea. mucosa of Endoderm

Its lower part divides into 2 lateral out pocketing called **bronchial buds**. / lung buds

The other coats of the respiratory system (muscles, cartilages, connective tissue, vessels) develop from the surrounding splanchnic mesoderm.

Bronchial tree


Fore brain
Foramen caecum
Thyroid Primordium
epiglottis
Tongue
laryngotracheal (respiratory) diverticulum.
Pericardium
stomodeum
bucco-pharyngeal membrane
oesophago-tracheal septum
Pharyngeal Part of Foregut.
Thyroglossal duct
endoderm
bilobed thyroid Primordium begins to descend.
Tongue
epiglottis
ruptured buccopharyngeal Membrane
epiglottis
laryngeal orifice
oerophagus
2 lung buds.
Tongue
hyoid bone
Thyroid gland
Trachea

Mesoderm
Muscle
Cartilage
Mucosa
Endoderm

Development of the larynx

Component of larynx		Origin
Cartilages	**Epiglottis**	lower Caudal part of the hypobranchial eminence (mesodermal).
	Other cartilages	4th and 6th pharyngeal arches (mesodermal).
Muscles	***Cricothyroid***	4th arch ex. laryngeal
	Other muscles	6th arch recurrent laryngeal
Mucous membrane	***Supraglottic area***	Int. laryngeal 4th arch (is supplied by superior laryngeal nerve).
	Infraglottic area	6th arch (is supplied by recurrent laryngeal nerve).

Bronchial tree:

During its separation from the foregut, the laryngeo-tracheal tube forms the trachea and two bronchial buds.

Each of these buds enlarges to form right and left main bronchi. The right then forms three secondary bronchi, and the left forms two secondary bronchi.

During further development, secondary bronchi divide repeatedly forming 10 tertiary (segmental) bronchi in the right lung and 8 in the left, creating **bronchopulmonary segments** of the adult.

Further, 17 generations of subdivisions of bronchi occur before birth.

Segment بين جوا ا

Then, 6 more generations are formed after birth.

(1st 10 years) لأن بعدكده زيادة حجم والـ alveoli عليها ت اضعافها

Congenital anomalies:

A- Anomalies of the lung

بتبقى لزيادة حجم الـ bronchi والـ alveoli

1- Respiratory distress syndrome: failure of the alveoli to ventilate adequately due to absence of the surfactant (a phospholipid- rich fluid capable of lowering surface tension at air-alveolar surface). Prevent lung collapse during expiration.

2- Ectopic lung lobes arising from the trachea or esophagus.

3- Congenital cysts of the lung: which are formed by dilation of terminal or larger bronchi.

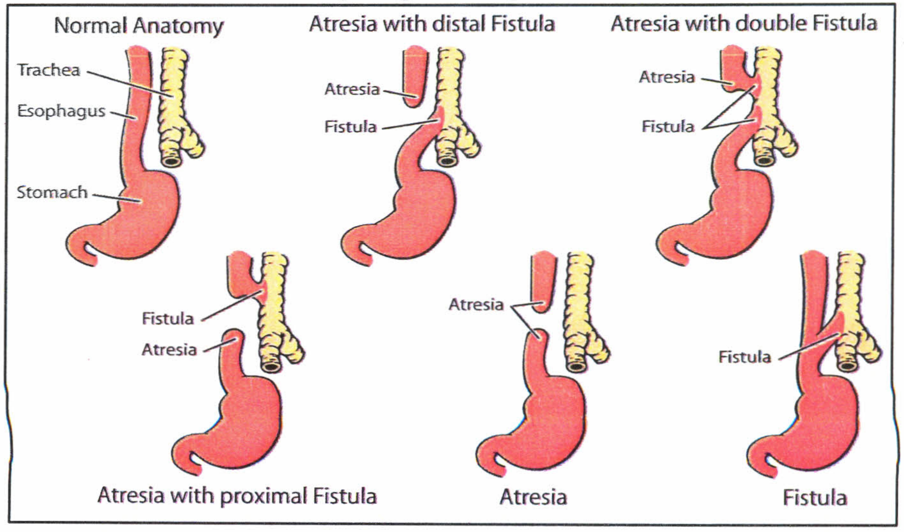
B- Esophageal atresia with or without tracheoesophageal fistula (فتحة في septum) Partial fusion between the ridges

[illegible] فتحة مقفولة [illegible]

It results either from posterior deviation of **tracheoesophageal septum** or from **mechanical factor** pushing the dorsal wall of foregut forward.

اتقفل من قدام

اتقفل ورا


Normal Anatomy
Trachea
Esophagus
Stomach
Atresia with distal Fistula
Atresia
Fistula
Atresia with double Fistula
Atresia
Fistula
Fistula
Atresia
Atresia with proximal Fistula
Atresia
Atresia
Fistula
Fistula

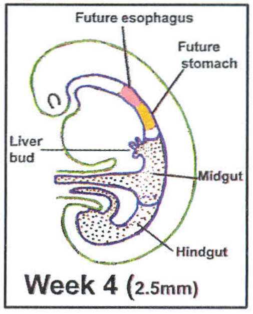
(Cranial end) Pharynx ما بعد

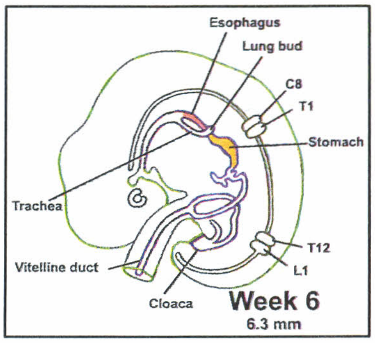
Derivatives of the caudal part of the foregut: endoderm

- lower part Esophagus.
- Proximal ½ of the duodenum.
- Stomach.
- Liver, gall bladder, pancreas.
  → Biliary System

Development of the esophagus

- It develops with the respiratory system. طبعاً مشتركة
- At first the esophagus is short but with the descent of the heart and lung it lengthens rapidly.
- Its mucosa is derived from endoderm of the foregut.
- The muscular coat is formed by the surrounding splanchnic mesoderm. اللي حواليه


Future esophagus
Future stomach
Liver bud
Midgut
Hindgut
Week 4 (2.5mm)


Esophagus
Lung bud
C8
T1
Stomach
Trachea
Vitelline duct
Cloaca
T12
L1
Week 6
6.3 mm

Development of the stomach

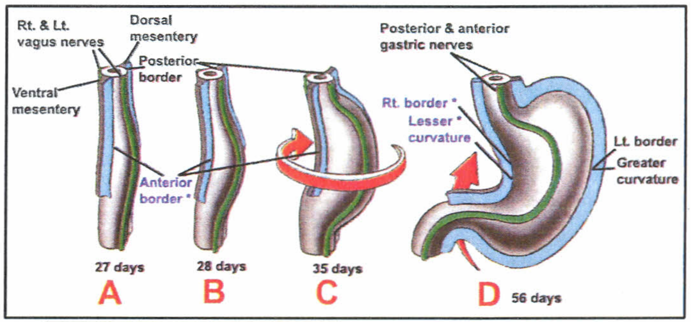
In the 5th week, the stomach appears as a fusiform dilatation. rt, lt ↑ Vagus ماشي علي (م)

It has: Two surfaces: right and left.

Two ends: upper (cardiac) & lower (pyloric).

Two borders: anterior and posterior.

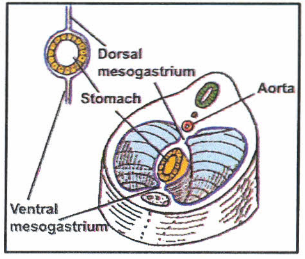
It is connected to the ventral and the dorsal body walls by ventral and dorsal mesogastria. (mesogastrium)

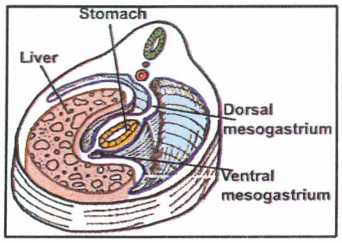

Rt. & Lt. vagus nerves
Dorsal mesentery
Posterior border
Ventral mesentery
Anterior border
Posterior & anterior gastric nerves
Rt. border
Lesser curvature
Lt. border
Greater curvature
27 days
28 days
35 days
56 days
A
B
C
D

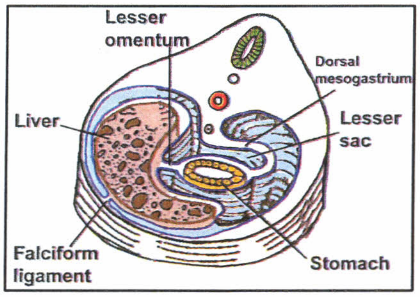
Shape and position of stomach change due to:

Differential growth:

- The posterior border grows faster than the anterior border.
- The posterior border becomes the greater curvature of the stomach.
- The anterior border becomes the lesser curvature of the stomach.


Dorsal mesogastrium
Stomach
Aorta
Ventral mesogastrium


Stomach
Liver
Dorsal mesogastrium
Ventral mesogastrium

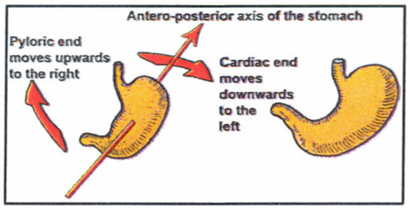

Lesser omentum
Liver
Dorsal mesogastrium
Lesser sac
Falciform ligament
Stomach

90° clockwise rotation around its longitudinal axis resulting in:

- The original left & right surfaces become the anterior & posterior surfaces of the stomach.
  lesser C. بدل قدام بقت يمين
  greater C. بدل ورا بقت شمال
- The original Lt and Rt vagi present on either side of the stomach become anterior and posterior gastric nerves respectively. (vagal trunks)
- The dorsal mesogastrium is pulled to left forming the lesser sac.

Stomach ورا ال Sac

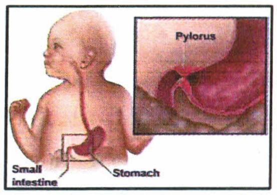
The stomach rotates around anterior-posterior axis so that the pyloric end moves to Rt and upward while the cardiac end moves to the Lt and downward. ✓ بعد ما كان الاتنين في ال midline


Antero-posterior axis of the stomach
Pyloric end moves upwards to the right
Cardiac end moves downwards to the left

Congenital anomalies:

Vomiting كتير

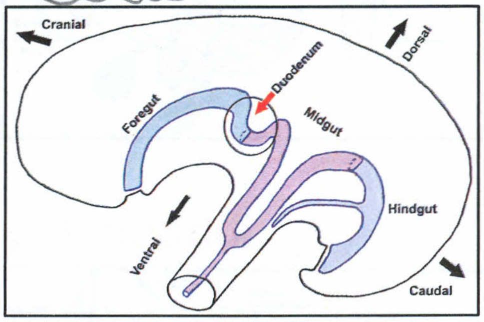
Congenital hypertrophic pyloric stenosis: **extreme thickening** of the circular smooth muscle of the pyloric sphincter, with **narrowing** of the lumen of the pylorus. or total obstruction.


Pylorus
Small intestine
Stomach

stomach تابع لـ

Development of the duodenum

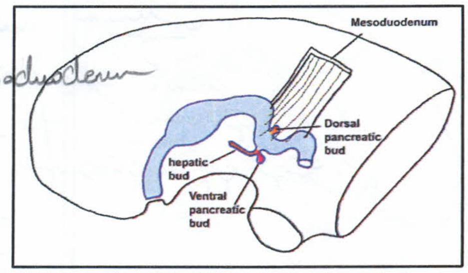
- **The duodenum develops** from both foregut (Caudal Part) and the midgut (Cranial Part). جزء من الـ dorsal mesentery
- **A duodenal loop** appears as a convex loop with a mesentery (mesoduodenum) connecting it to the posterior abdominal wall. لما تتكون الـ C الـ Convexity هي anterior part طالع منه الـ hepatic bud اللي هيعمل liver, gallb., و biliary


Cranial
Dorsal
Foregut
Duodenum
Midgut
Hindgut
Ventral
Caudal

The position of duodenum changes due to:

1) Rotation of the stomach 90° clockwise along longitudinal axis rotates the duodenal loop to the Right. شايلك في duodenum عمل Common bile duct
2) Differential growth of the duodenal walls, so the common bile duct will open into the postero-medial wall of the duodenum. (2nd part of duodenum) كدة الـ common bile duct فاتحة في الـ 2nd part
3) Absorption of the mesoduodenum: duodenum becomes retro-peritoneal except its 1st inch. نتيجة للـ rotation بيحصل الـ mesoduodenum مع parietal peritoneum بتاع الـ PAW (١-٣ متغطي بس)

During the 2nd month, the lumen of the duodenum is obliterated by proliferation of the cells in its lumen. However the lumen is recanalized shortly after that


Mesoduodenum
Dorsal pancreatic bud
hepatic bud
Ventral pancreatic bud

Congenital anomalies of the duodenum:

1) Anomalies of the mesoduodenum:

Persistence of parts of the mesoduodenum forms ~~duodenal~~ Para or retro folds and duodenal recesses. These recesses may be sites for internal hernia.

2) Stenosis or atresia of duodenum: due to incomplete recanalization.

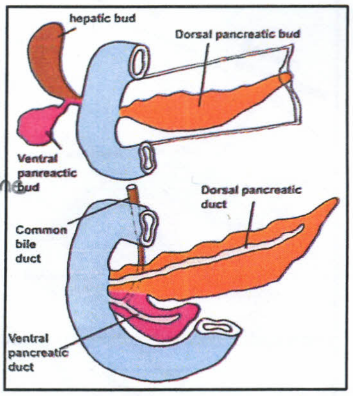
Development of the pancreas

تابع لـ duodenum in PAW, retroPeritoneal mixed gland endocrine exocrine

The pancreas develops from the duodenum by 2 buds:

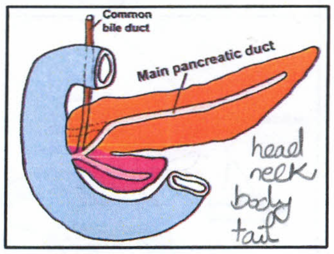
Dorsal pancreatic bud: arises from the dorsal wall of the duodenum. ماشي جوا الـ mesoduodenum

Ventral pancreatic bud: arises from ventral wall of the duodenum in conjunction with the hepatic bud. لازم يتقابلوا عشان يبقوا حتة وا


hepatic bud
Dorsal pancreatic bud
Ventral panreactic bud
Dorsal pancreatic duct
Common bile duct
Ventral pancreatic duct

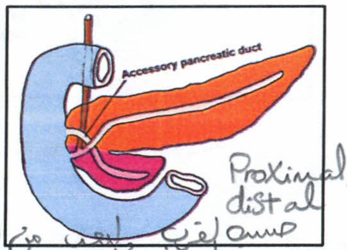
Ventral pancreas comes to lie below and behind the dorsal pancreas as a result of: Migration

- Differential growth of the duodenal wall.
- Axial rotation of the duodenum to right side. 90° ClocK wise


Common bile duct
Main pancreatic duct
head
neck
body
tail

Later, the parenchyma (Glandular tissue) & duct systems of the 2 buds fuse together:

- The ventral bud forms:
  - Uncinate process. - Inferior part of the head (of the head) of the pancreas.
- The dorsal bud forms the remaining part of pancreas. بقية الـ head + neck, body, tail
- The main pancreatic duct is formed by the distal part of the dorsal pancreatic duct and the whole ventral pancreatic duct. بتبدأ من الـ tail وتروح للـ head وتتقابل مع الـ Common bile
- The proximal part of the dorsal pancreatic duct is either obliterated or persists as the accessory pancreatic duct. (Minor) ويتقابلوا في Ampulla of Vater. (Major duodenal papilla) 1 inch ومن major تحت


Accessory pancreatic duct
Proximal, distal

بعيد عن بعض، واحد من الـ duodenum

- The islets of Langerhans: develop in 3rd month, start insulin secretion during 5th month. intrauterine

Splanchnic mesoderm forms the pancreatic connective tissue. bvs

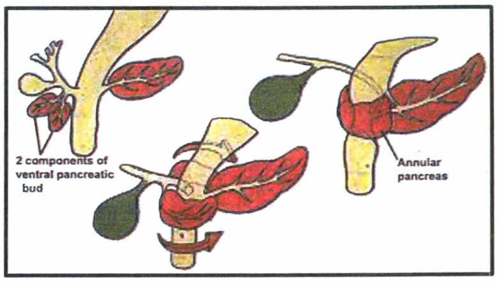
Parenchyma > endoderm of foregut

Congenital anomalies of the pancreas:

1- Accessory pancreatic tissue: may be found in the wall of stomach or duodenum., esophagus, jejunum.

2- Annular pancreas: the duodenum is completely surrounded by pancreatic tissue.

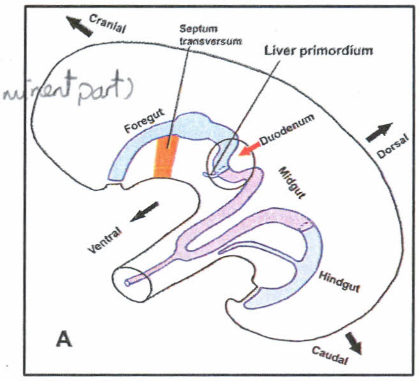
The ventral pancreatic bud consists of 2 components. A portion migrates along its normal route and the other part migrates in the opposite direction. Bilobed

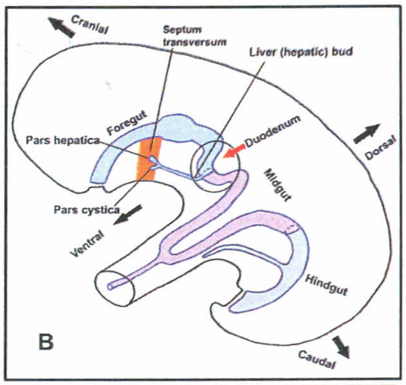

2 components of ventral pancreatic bud
Annular pancreas

Development of the liver and gall bladder

The liver primordium appears in the 3rd week as outgrowth from the lower end of the foregut. Ventral part (most prominent part) of duodenum

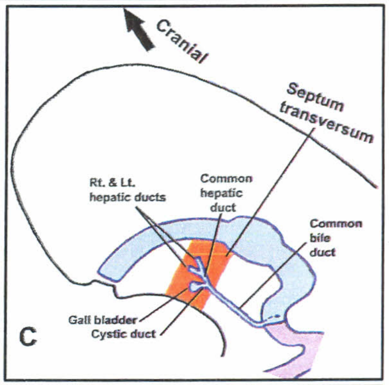
The liver bud elongates, penetrates inferior part of the septum transversum. It divides into two parts: **Pars hepatica** & **Pars cystica**.


Cranial
Septum transversum
Liver primordium
Foregut
Duodenum
Dorsal
Midgut
Ventral
Hindgut
A
Caudal


Cranial
Septum transversum
Liver (hepatic) bud
Pars hepatica
Foregut
Duodenum
Dorsal
Pars cystica
Midgut
Ventral
Hindgut
B
Caudal

Pars Hepatica

- It forms the common hepatic duct, which divides into right and left hepatic ducts.
- Each hepatic duct branches into multiple cords of the liver cells.
- The hepatic cords will differentiate into:
  . Hepatocytes. ماشيين بالعكس
  . Epithelial lining of the intrahepatic part of the biliary system. (bile canaliculi)
- Hepatic sinusoids are derived from the 2 vitelline & the 2 umbilical veins which are broken down by the developing hepatic cords. عالة كتيرة
- Liver capsule is mesodermal (derived from ventral mesogastrium).


Cranial
Septum transversum
Rt. & Lt. hepatic ducts
Common hepatic duct
Common bile duct
Gall bladder
Cystic duct
C

Pars Cystica

- It forms a dilated part (gall bladder) & its stem forms the cystic duct. (Distal part) (proximal part)
- The original stem of the hepatic bud forms the common bile duct. اللي اسمه ماسك ف duodenum not Pars H or C

Pericardial cavity the dueso تانى

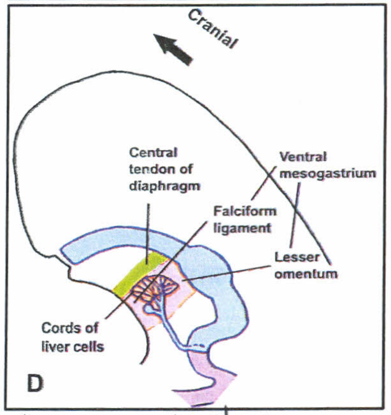
The septum transversum is divided by growth of the liver into:

A caudal region (ventral mesogastrium): is invaded by the developing liver, gives rise to: becomes membranous (lower part of septum transversum)

- Lesser omentum between stomach and liver.
- Falciform ligament between liver and anterior abdominal wall.
- Visceral peritoneum of liver including coronary and triangular ligaments. ترتبط بال وبـ PAW و فوق ل diaphragm

A cranial region: This will give rise to central tendon of diaphragm. + capsule

membranous بس، mesoderm تانى تخين densely packed


Cranial
Central tendon of diaphragm
Ventral mesogastrium
Falciform ligament
Lesser omentum
Cords of liver cells
D

The size and weight of the liver

- By 10th week, the liver is about 10% of the total body weight. It was a hemopoietic organ. hematopoietic كان لسه مفيش bone marrow
- At birth the liver forms only 5% of the total body weight. → 2%

liver transplantation & تاع

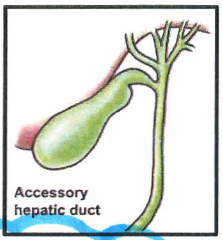
Congenital anomalies:

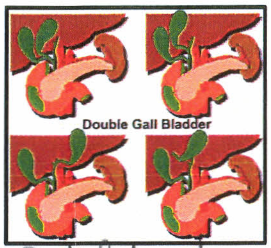
جوا

1- **Biliary atresia:** intrahepatic or extrahepatic.

2- **Accessory hepatic ducts.**

3- **Duplication of gall bladder.**





Development of the midgut

lower part of duodenum, jejunum, ileum, caecum, Appendix, A.C, rt colic flexure, rt 2/3 of transverse colon.

The midgut begins caudal to the liver bud and extends to the junction of the right ⅔ and left ⅓ of the transverse colon in the adult.

→ at junction between foregut & Midgut.

It is connected with the 2^{ry} yolk sac by the vitelline duct.

Formation of the U-shaped loop:

Mid gut or intestinal loop

The midgut elongates to form a U-shaped loop which has:

a) **Apex:** is connected with the yolk sac by the vitello-intestinal duct.

b) **Cephalic limb:** (Cranial) forms the distal part of duodenum, jejunum and part of (most) ileum.

c) **Caudal limb:** forms part of ileum, caecum, appendix, ascending colon and right ⅔ of the transverse colon.

rt colic flexure

A caecal swelling appears in the caudal limb

قريب من ال apex

→ future caecum

Physiological umbilical hernia:

- As a result (نتيجة) the rapid growth and expansion of the liver, the abdominal cavity becomes too small to accommodate all the intestinal loops.

شهر ونص

- The loops leave the abdominal cavity and enter the umbilical cord about the 6th week.

Reduction of physiological umbilical hernia:

- With enlargement of the abdominal cavity, the herniated intestinal loops begin to return to the abdominal cavity during 10th week of development.
- The loops return to the abdominal cavity in a special order:

. **Proximal part of jejunum** (of cranial limb) is the first part to enter the abdominal cavity and lies on Lt. side.

. **The next returning loops** gradually lie more to the right. الانتقال تتركب من الشمال لليمين

. **The caecal swelling** (of caudal limb) is the last to return the abdomen; it lies below Rt. lobe of liver. It then descends into Rt. iliac fossa thus forming the Rt. colic flexure and ascending colon.

Rotation of the intestinal loop:

- In the same time in which the intestinal loop is elongating, it rotates around an axis formed by the superior mesenteric artery.
- The rotation takes place anticlockwise for 270°:
  - 90° during herniation. تجي يمين Cranial limb, تجي شمال Caudal limb
  - 180° during the return. اليمين تجي شمال , والعكس

Congenital anomalies of the midgut:

mesentery اللي احتفظ بال ileum, jejunum, transverse colon

1- Anomalies of the mesenteries:

- **Mobile caecum:** persistence of a (lower) portion of the mesocolon (of A.C).

طبيعي mesentery in front & sides only

تكتفي، Parietal Perit. a new of PAW المفروض تلحم مع ماليس مثبت لحموا بتاع

- **Incomplete fusion of the mesentery** of the colon may give rise to retrocolic pockets behind the ascending mesocolon. may cause hernia

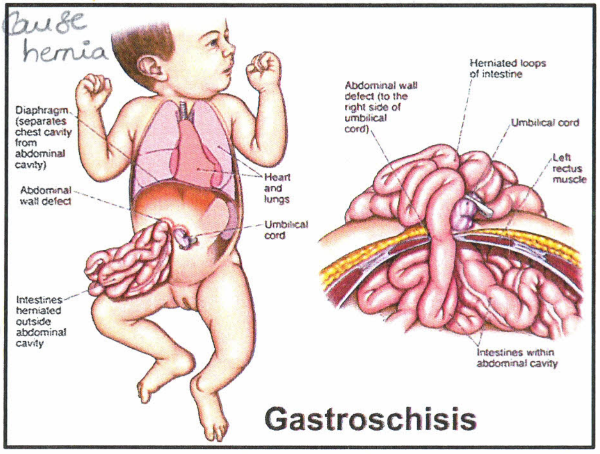
2- Body wall defect:

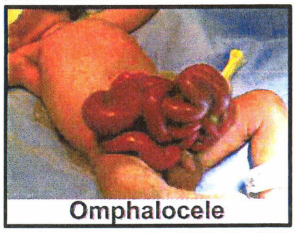
زي البالونة umbilical Cord

- **Omphalocele:** due to failure of the bowel to return to body cavity. herniation e'out reduction
- **Gastroschisis:** protrusion of abdominal contents lateral to umbilicus. (Paraumbilical)

مالهاش غشاء liver, int. loops, stomach

- **Umbilical hernia:** infantile The intestines return to the abdomen during the 10th week and then herniated through imperfectly closed umbilicus. / بيحصل تاني

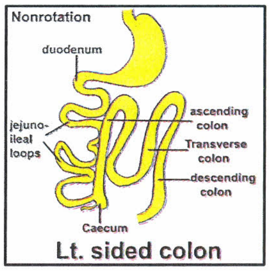

Diaphragm (separates chest cavity from abdominal cavity)
Abdominal wall defect
Heart and lungs
Umbilical cord
Intestines herniated outside abdominal cavity
Abdominal wall defect (to the right side of umbilical cord)
Herniated loops of intestine
Umbilical cord
Left rectus muscle
Intestines within abdominal cavity
Gastroschisis

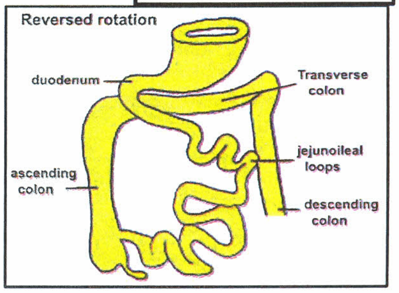

Omphalocele

Umbilical hernia

3- Abnormal rotation of the midgut loop:

- If rotation occurs for only 90° → Lt. sided colon:


Nonrotation
duodenum
jejuno-ileal loops
ascending colon
Transverse colon
descending colon
Caecum
Lt. sided colon


Reversed rotation
duodenum
Transverse colon
jejunoileal loops
ascending colon
descending colon

caudal limb

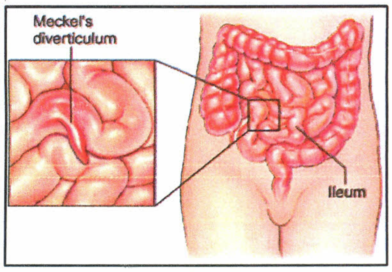
. The colon & caecum will be first parts to return and settle on the Lt. side of the abdomen.

. The later returning intestinal loops will become located to the Rt. Side.

90° clockwise during herniation

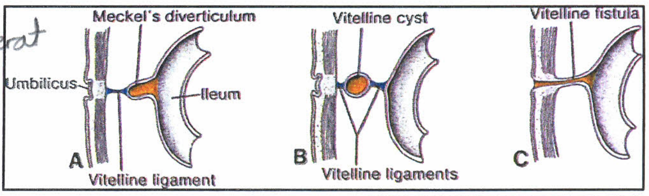
- Reversed rotation of the intestinal loop:

The transverse colon will pass behind the duodenum.


Meckel's diverticulum
Ileum

4- Remnants of the vitelline duct:

المفروض ضموره complete degenerat

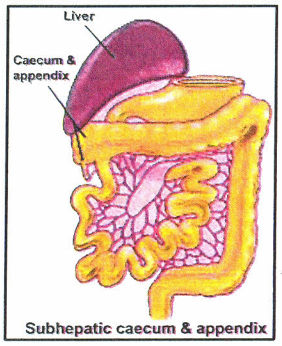

Meckel's diverticulum
Vitelline cyst
Vitelline fistula
Umbilicus
Ileum
A
Vitelline ligament
B
Vitelline ligaments
C

- **Meckel's diverticulum:** is the persistence of the proximal part of the vitelline duct.
- **Vitelline fistula:** the whole vitelline duct remains open forming a direct connection between the intestine and the umbilicus.
- **Vitelline cyst:** Both ends of the vitelline duct change to fibrous cords while its middle forms a large cyst.

انسداد كامل ضيق

5- Atresia and stenosis of any part of the intestinal loop.

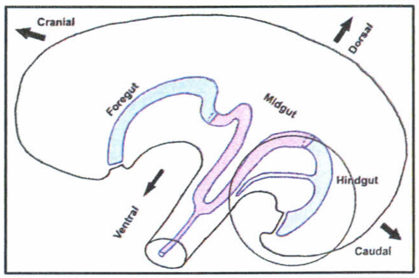
6- Subhepatic caecum and appendix: as a result of failure of descent of caecum. ✓


Liver
Caecum & appendix
Subhepatic caecum & appendix

Development of the hindgut

It is the part found in the tail fold extending from left ⅓ of the transverse colon till cloacal membrane.

It gives rise to: Lt ⅓ of transverse colon, descending colon, sigmoid colon, rectum and upper part of anal canal.

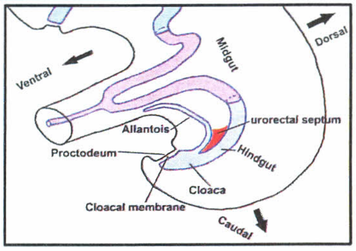

Cranial
Dorsal
Foregut
Midgut
Hindgut
Ventral
Caudal

The part of hindgut caudal to the origin of allantois is called **the cloaca.**

Cloacal membrane forms the ventral boundary of the cloaca.

Development of rectum and upper part of anal canal:

A transverse ridge **(urorectal septum)** arises in the angle between allantois and hindgut.

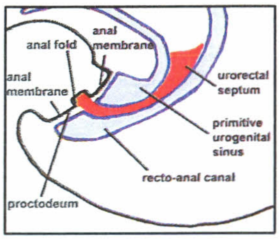

Ventral
Midgut
Dorsal
urorectal septum
Allantois
Proctodeum
Hindgut
Cloaca
Cloacal membrane
Caudal

This septum grows caudally dividing the cloaca into:

- * An anterior part called the primitive urogenital sinus.
- * A posterior part called the recto-anal canal.

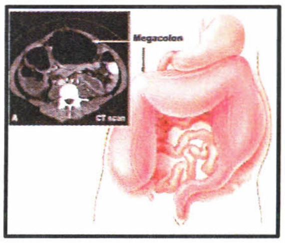
It also divides the cloacal membrane into:

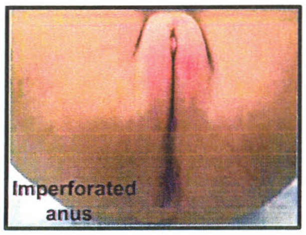
- * A urogenital membrane (in front).
- * An anal membrane (behind).


anal fold
anal membrane
anal membrane
urorectal septum
primitive urogenital sinus
recto-anal canal
proctodeum

Development of the lower part of the anal canal

- The mesoderm around the anal membrane proliferates to from anal folds.
- The anal membrane lies in the bottom of the proctodeum or anal pit.
- The anal membrane then ruptures at the 7th week.
- So anal canal is of double origin; upper part is endodermal & lower part is ectodermal in origin


Megacolon
A
CT scan

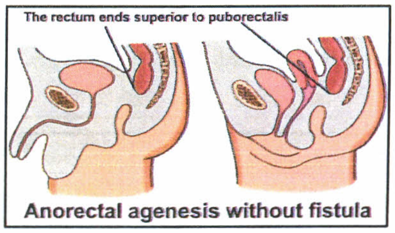

Imperforated anus

Congenital malformation:

1. Congenital (aganglionic) megacolon: (Hirschsprung disease):

It is due to absence of parasympathetic ganglia in the bowel wall.

2. Imperforated anus: it occurs due to failure of the anal membrane to break down.

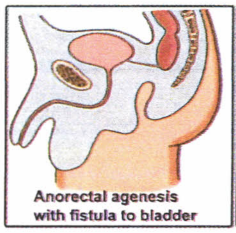

The rectum ends superior to puborectalis
Anorectal agenesis without fistula

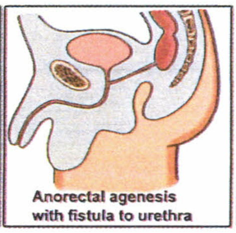
3. Anorectal Agenesis, with or without a fistula:

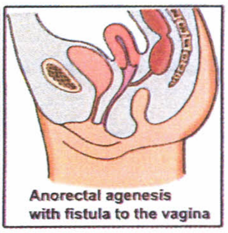
* The rectum ends superior to puborectalis muscle.

* There is usually a fistula:

- To bladder (recto-vesical fistula) or urethra (rectourethral fistula) in male.
- To the vagina (recto-vaginal fistula) in female.


Anorectal agenesis with fistula to bladder

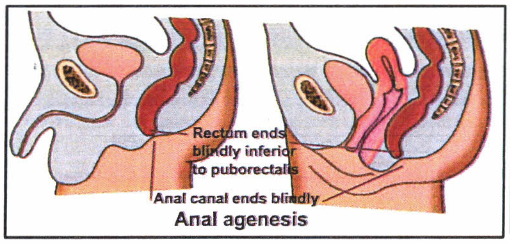

Anorectal agenesis with fistula to urethra

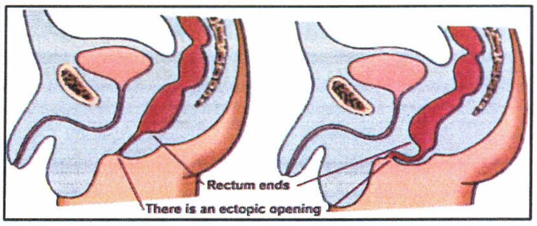

Anorectal agenesis with fistula to the vagina

4. Anal Agenesis, with or without a fistula:

* The rectum ends inferior to the puborectalis muscle.

* The anal canal may end blindly or there may be an ectopic opening.

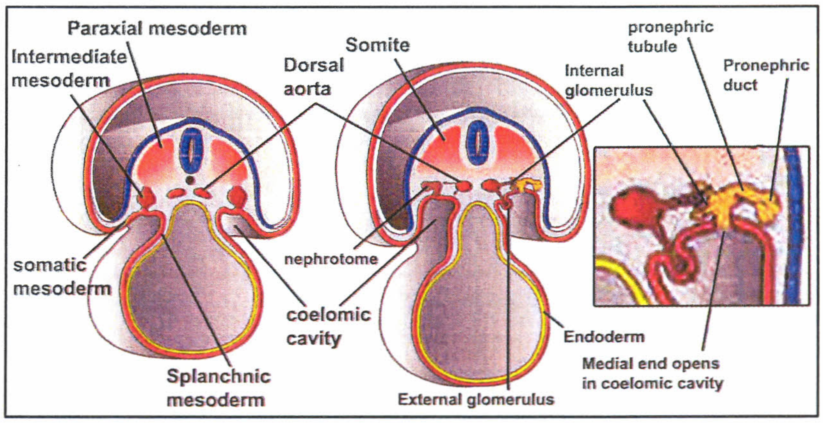

Rectum ends blindly inferior to puborectalis
Anal canal ends blindly
Anal agenesis


Rectum ends
There is an ectopic opening

Development of the kidney and the ureters

- The excretory part of the urinary system develops from three overlapping kidney systems which are formed in a cranial to caudal sequence during intrauterine life.
- These systems are: the ***Pronephros, Mesonephros*** and ***Metanephros.***
- They develop from the intermediate plate mesoderm.

A) Pronephros


Paraxial mesoderm
Intermediate mesoderm
Somite
Dorsal aorta
pronephric tubule
Internal glomerulus
Pronephric duct
somatic mesoderm
nephrotome
coelomic cavity
Endoderm
Medial end opens in coelomic cavity
Splanchnic mesoderm
External glomerulus

Site: cervical region.

Structure:

1. Pronephric tubules:

They are 7-10 tubules are arranged one caudal to the other.

Each tubule has 2 ends

- Medial end:

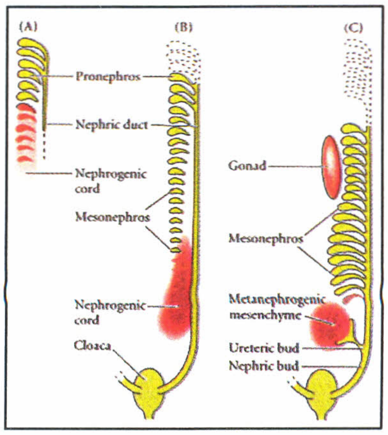
a) Is connected with coelomic cavity.

b) It has internal glomerulus (the tuft of capillaries invaginates the tubules).

c) It also has external glomerulus (the tuft of capillaries invaginates the coelomic cavity).

- Lateral end: opens in the pronephric duct.

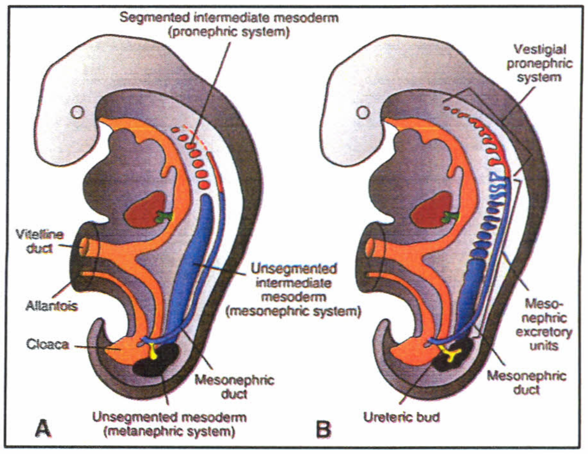
2. Pronephric duct: Extends downwards to open into the cloaca.


(A)
(B)
(C)
Pronephros
Nephric duct
Nephrogenic cord
Mesonephros
Nephrogenic cord
Cloaca
Gonad
Mesonephros
Metanephrogenic mesenchyme
Ureteric bud
Nephric bud

Fate:

- **Pronephric tubules:** degenerate completely.
- **Pronephric duct:** persists and forms mesonephric duct for the developing mesonephros.

B) Mesonephros


Segmented intermediate mesoderm (pronephric system)
Vestigial pronephric system
Vitelline duct
Allantois
Cloaca
Unsegmented intermediate mesoderm (mesonephric system)
Mesonephric duct
Unsegmented mesoderm (metanephric system)
A
B
Ureteric bud
Meso-nephric excretory units
Mesonephric duct

Site: thoracic and upper lumbar regions.

Structure:

1- Mesonephric tubules:

They are 70-80 tubules are (one caudal to the other).

Each tubule is S-shaped and has 2 ends:

Medial end:

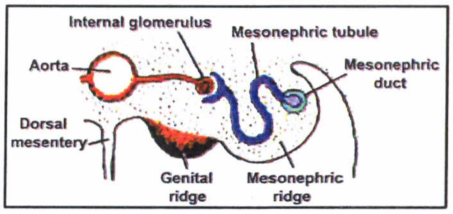
- It is not connected to the coelomic cavity.
- It has only an internal glomerulus.

Lateral end: opens into the mesonephric duct.

2. Mesonephric duct (Wolffian duct):

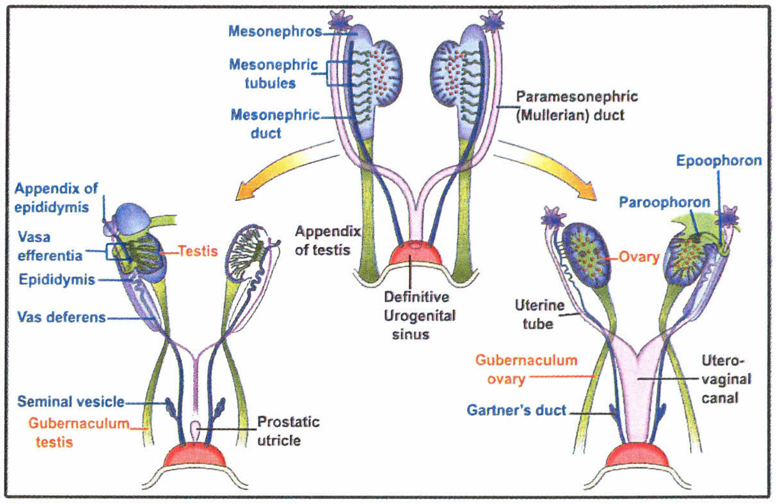
It is the remaining part of the pronephric duct.

It extends caudally to open into the cloaca.


Internal glomerulus
Mesonephric tubule
Aorta
Mesonephric duct
Dorsal mesentery
Genital ridge
Mesonephric ridge

Fate:

	In male	In female
Mesonephric tubules	- Vasa efferentia and head of epididymis. - Paradidymis (mesonephric remnants).	Epoophron Paroophron
Mesonephric duct	- Appendix of epididymis (mesonephric remnants). - Body and tail of epididymis. - Vas deferens, seminal vesicle and ejaculatory duct.	Gartner's duct.
	Ureteric bud and trigone of urinary bladder.	

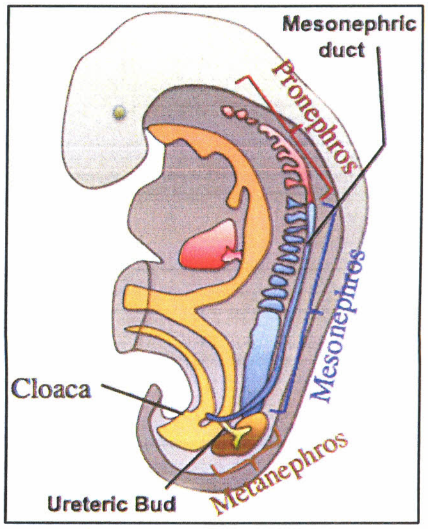

Mesonephros
Mesonephric tubules
Mesonephric duct
Paramesonephric (Mullerian) duct
Epoophoron
Paroophoron
Ovary
Appendix of epididymis
Vasa efferentia
Testis
Epididymis
Vas deferens
Appendix of testis
Definitive Urogenital sinus
Uterine tube
Gubernaculum ovary
Utero-vaginal canal
Gartner's duct
Seminal vesicle
Gubernaculum testis
Prostatic utricle

C) Metanephros (Permanent Kidney)

A- It develops from 2 sources:

1) Ureteric bud:

- The ureteric bud arises as a diverticulum from the lower end of the mesonephric duct.
- It grows cranially penetrating the metanephric cap.
- The stalk of ureteric bud becomes the ureter. Its expanded cranial end forms the renal pelvis.
- Its cranial end undergoes repeated branching forming successive generations of collecting tubules:
  - * The first four generations form major calyces.
  - * The second four generations form the minor calyces.
  - * The remaining generations form the collecting tubules.


Mesonephric duct
Pronephros
Mesonephros
Cloaca
Ureteric Bud
Metanephros

2) Metanephric cap:

- Each collecting tubules is covered at its distal end by metanephric cap (derived from the nephrogenic cord in the sacral region).
- The metanephric caps form the renal vesicles, which give rise to the metanephric tubules.
- Capillaries grow into proximal end of the tubules and differentiate into glomeruli.

B- Further growth of the kidney:

- The tubules together with their glomeruli form nephrons.
- **The proximal end** of each nephron forms Bowman's capsule while **the distal end** opens into a collecting tubule.
- Continuous lengthening of the nephron results information of the proximal convoluted tubules, loop of Henle and distal convoluted tubules.

C- Final growth of the kidney:

- **Changes in shape:** At first the kidney was lobulated. Then it becomes smooth.
- **Ascent of the kidney:**

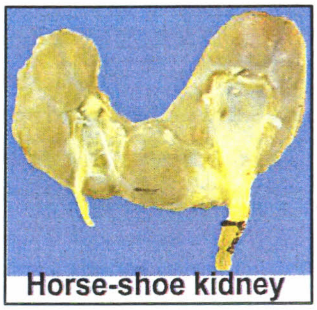
* Initially, the kidney lies in the pelvic region.

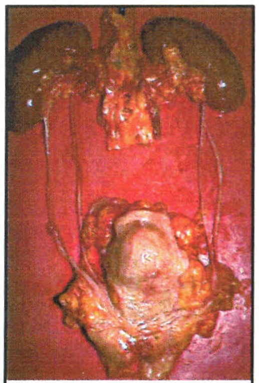
* Later, it shifts upwards in abdomen.

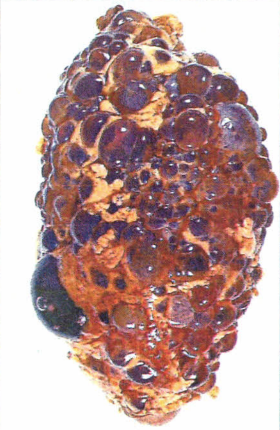
- **Medial rotation:**
  - * Initially the hilum of the kidney faces **ventrally.**
  - * As the kidney ascends **it rotates medially 90°**.
- **Change in the blood supply:** As it ascends it changes its blood supply:
  - * 1st from common iliac artery.
  - * Finally from abdominal aorta.

Congenital anomalies of the kidney:

1. **Renal agenesis:** unilateral or bilateral absence of kidney.
2. **Pelvic kidney:** one kidney may fail to ascend and remains in the pelvis.
3. **Horse-shoe kidney:** It is due to fusion of the lower poles of the 2 kidneys across the midline.


Horse-shoe kidney


Double ureter


Congenital polycystic kidney

4. **Accessory renal arteries:** represent the persistence of embryonic vessels
5. **Congenital polycystic kidney**

   It is a numerous cyst form.

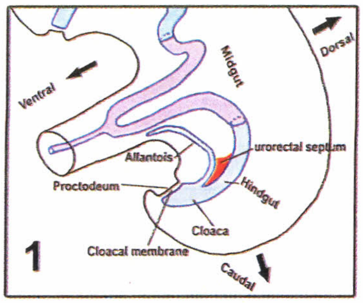
   It may be inherited as autosomal recessive or dominant disorder.
6. **Duplications of the Urinary Tract:**
   - a) Duplications of abdominal part of the ureter and the renal pelvis
     - * Incomplete division of ureteric bud → bifid ureter.
     - * Complete division results in a double kidney with a bifid ureter.
   - b) A supernumerary kidney with its own ureter: it is due to formation of two ureteric buds.
7. **Ectopic Ureter:** it opens anywhere except into the urinary bladder.

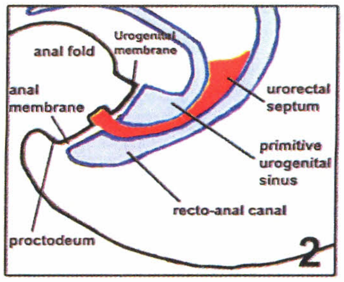
Cloaca

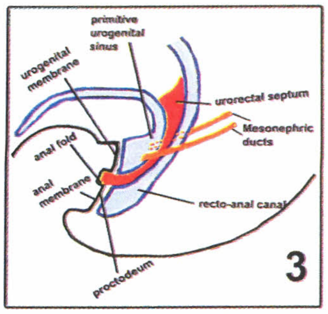
Definition: Is the expanded caudal part of the hindgut (caudal to the origin of the allantois).

Development of the cloaca:

- An urorectal septum arises in the angle between allantois and hindgut.
- This septum grows caudally dividing the cloaca into:
  - * An anterior part (**primitive urogenital sinus**).
  - * A posterior part (**recto-anal canal).**


Ventral
Midgut
Dorsal
Allantois
urorectal septum
Proctodeum
Hindgut
Cloaca
Cloacal membrane
Caudal
1


anal fold
Urogenital membrane
anal membrane
urorectal septum
primitive urogenital sinus
recto-anal canal
proctodeum
2


primitive urogenital sinus
urogenital membrane
urorectal septum
Mesonephric ducts
anal fold
anal membrane
recto-anal canal
proctodeum
3

- It also divides the cloacal membrane into:
  - * A urogenital membrane (in front).
  - * An anal membrane (behind).

Subdivision of the primitive urogenital sinus:

The primitive urogenital sinus is subdivided by point of entrance of the mesonephric duct into:

* Vesicourethral canal -------------- the upper part

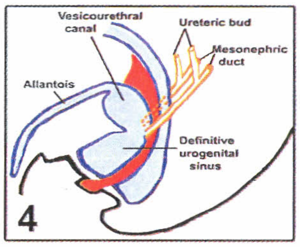
* Definitive urogenital sinus -------- the lower part. Its upper segment is called the pelvic part. Its lower segment is called the phallic part.

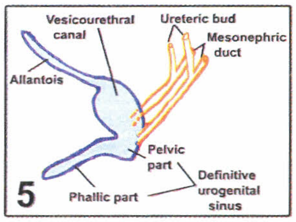
Fate of vesicourethral canal and definitive uroaenital sinus:

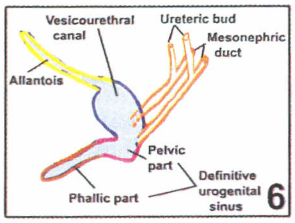
Vesicourethral canal:

a) Urinary bladder except trigone.

b) Preprostatic and upper ½ of prostatic urethra (in ♂), the whole urethra (in ♀).


Vesicourethral canal
Ureteric bud
Mesonephric duct
Allantois
Definitive urogenital sinus
4


Vesicourethral canal
Ureteric bud
Mesonephric duct
Allantois
Pelvic part
Definitive urogenital sinus
Phallic part
5


Vesicourethral canal
Ureteric bud
Mesonephric duct
Allantois
Pelvic part
Definitive urogenital sinus
Phallic part
6

Definitive uroaenital sinus:

a) Pelvic part of urogenital sinus gives rise to lower ½ of prostatic and membranous urethra (in ♂)

b) Phallic part of the urogenital sinus:

- It is flattened from side to side, and as the genital tubercle grows, this part of the sinus will be pulled ventrally.
- It gives rise to most of the spongy urethra (in ♂) and vestibule of vagina (in ♀)

Development of the urinary bladder

Definition:

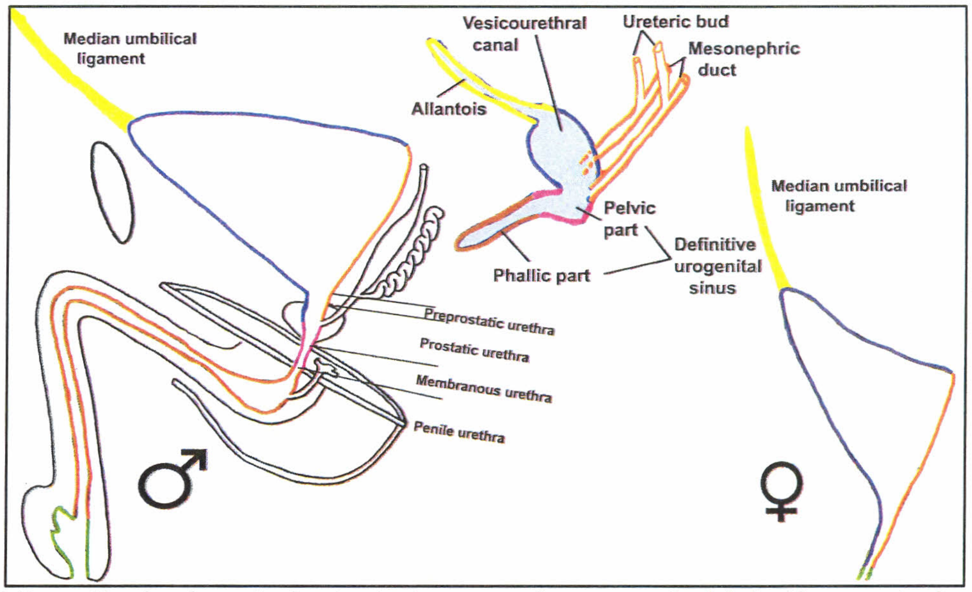
1- **Vesicourethral canal:** forms the urinary bladder except the trigone.

2- **Allantois:**

- Its proximal part is incorporated into the bladder.
- Its distal part becomes fibrosed to form urachus. In the adult the urachus is represented by the **median umbilical ligament**

3- **Lower parts of the 2 mesonephric ducts:** form the trigone.

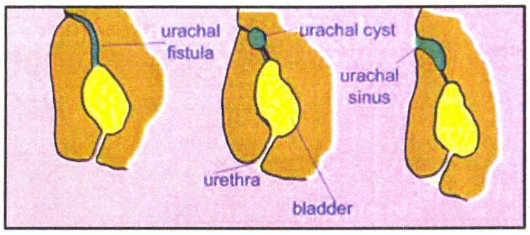
- The mesonephric ducts open early into the vesicourethral canal.


Median umbilical ligament
Vesicourethral canal
Ureteric bud
Mesonephric duct
Allantois
Pelvic part
Definitive urogenital sinus
Phallic part
Median umbilical ligament
Preprostatic urethra
Prostatic urethra
Membranous urethra
Penile urethra
♂
♀

- Then their distal portions and the attached ureteric ducts become incorporated into the posterior wall of the bladder.
- So the 2 mesonephric ducts and 2 ureters open separately into the urinary bladder.
- Finally: * The two ureters open in the posterior wall of the urinary bladder.
  * The two ejaculatory ducts open in the upper part of the prostatic urethra.

Congenital anomalies of the bladder:

1. Persistence of a patent urachus:



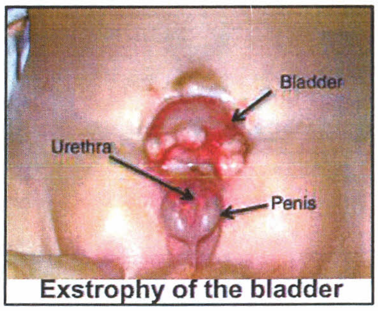
- Urachal fistula: Persistence of the whole urachus patent.
- Urachal cyst: Persistence of an isolated segment of the urachus patent.
- Urachal sinus: persistence of upper part of the urachus.

2. Exstrophy of the bladder:

It is a ventral body wall defect in which bladder mucosa is exposed.

It may be caused by a lack of mesodermal migration between the umbilicus & genital tubercle.

This is followed by rupture of covering ectoderm.



Exstrophy of the bladder

Development of the Urethra

Development of the male urethra:

1) Preprostatic and Upper part of prostatic urethra: is derived from:

Vesicourethral canal and absorbed parts of the mesonephric ducts.

2) Lower part of the prostatic urethra and membranous urethra:

It is derived from the pelvic part of the definitive urogenital sinus

3) Spongy (penile) urethra :

The endodermal cells lining the lumen of the phallic part of the definitive urogenital sinus proliferate to form the urethral plate.

The phallus pulls the urethral folds so that they form lateral walls of the urethral groove.

This groove does not reach the most distal part of the elongated phallus.

The urethral canal:

It is formed by the meeting and fusion of the urethral folds together.

It ends blindly anteriorly at the glans penis.

4) The terminal (glandular) part:

It develops by a cord of ectodermal cells that grows from the tip of the glans penis.

Finally, this cord becomes canalized and communicates with the urethral canal.

Development of the female urethra: It develops from the vesico-urethral canal and absorbed parts of the mesonephric ducts.

Congenital anomalies of male urethra:

Hypospadius

The urethra opens on under surface of the penis.

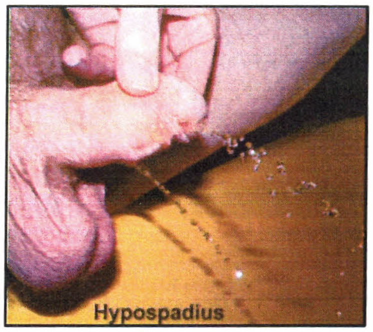
It is due to failure of fusion of the edges of the urethral groove.

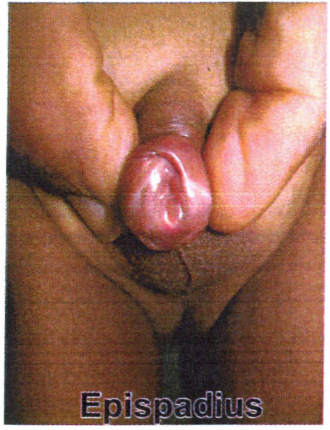
Epispadius:

The urethra opens on dorsum of the penis.

It is due to development of the genital tubercle in the cloacal membrane opposite the urorectal septum.

When this membrane ruptures, the outlet comes to lie on the cranial aspect of the penis.


Hypospadius

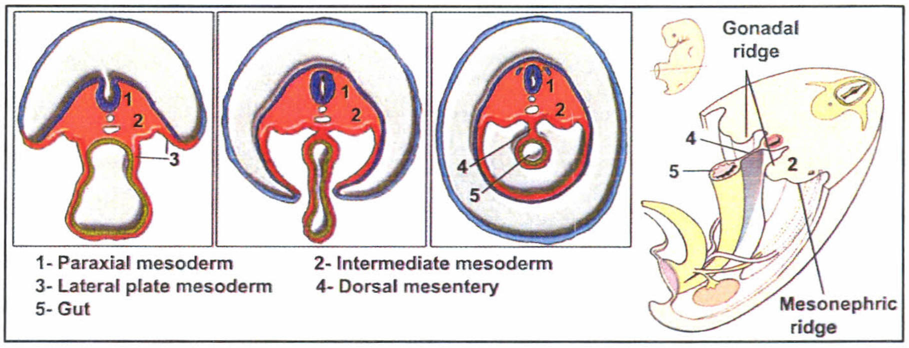

Epispadius

Development of the gonads

I) Indifferent gonads:

Although sex of the embryo is determined at time of fertilization, it is impossible to know the sex gland is an ovary or a testis until 7th week.

Before this time the sex gland is called "the indifferent gonad".


1
2
3
4
5
Gonadal ridge
Mesonephric ridge
1- Paraxial mesoderm
2- Intermediate mesoderm
3- Lateral plate mesoderm
4- Dorsal mesentery
5- Gut

Sources:

1. Intermediate mesoderm: (genital or gonadal ridge)

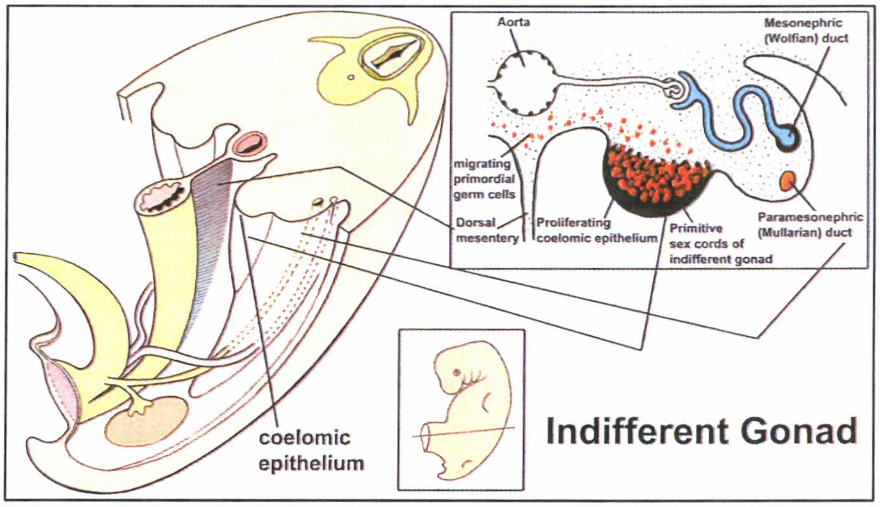
The genital ridge lies on the medial side of the mesonephros.

It gives the stroma of the gland.

2- Coelomic epithelium:

It consists of mesothelial cells (which line the coelomic cavity).

Mesothelial cells overlying the genital ridge proliferate and penetrate the underlying mesoderm forming the primitive sex cords of indifferent gonad.


Aorta
Mesonephric (Wolfian) duct
migrating primordial germ cells
Dorsal mesentery
Proliferating coelomic epithelium
Primitive sex cords of indifferent gonad
Paramesonephric (Mullarian) duct
coelomic epithelium
Indifferent Gonad

3- Primordial germ cells:

They are endodermal cells which arise from the wall of yolk sac.

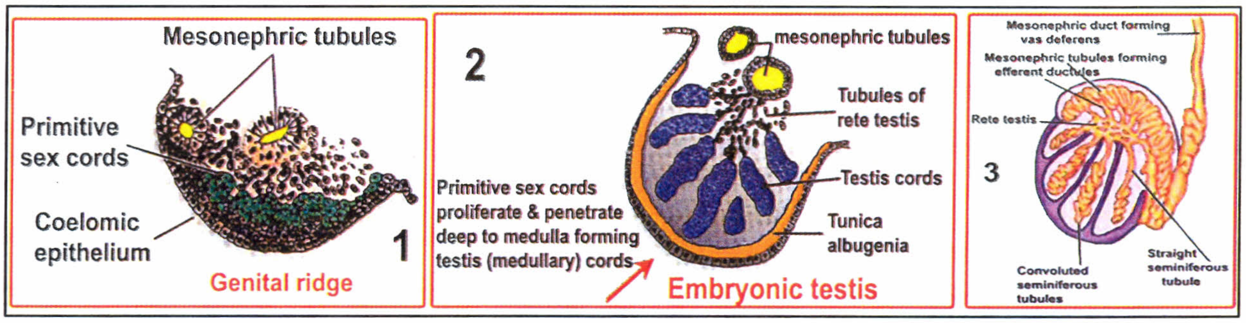
They proliferate and migrate along dorsal mesentery of hindgut to reach the genital ridge.

They have inductive influence on the development of the gonad into ovary or testis.

II) Development of the testis:

A- Steps of development of the testis:

- Under influence of the SRY (sex determining region on Y chromosome), the primitive sex cords continue to proliferate and penetrate deep into the medulla forming the testis (medullary) cords.
- Towards the hilum of the gland, the cords break up forming the tubules of the rete testis.
- Testis cords then lose their connection with the surface epithelium and become separated from the epithelium by tunica albuginea.
- Testis cords become horse shoe-shaped (seminiferous tubules) and their extremities are continuous with the rete testis.


Mesonephric tubules
Primitive sex cords
Coelomic epithelium
1
Genital ridge
2
mesonephric tubules
Tubules of rete testis
Testis cords
Tunica albugenia
Primitive sex cords proliferate & penetrate deep to medulla forming testis (medullary) cords
Embryonic testis
Mesonephric duct forming vas deferens
Mesonephric tubules forming efferent ductules
Rete testis
3
Convoluted seminiferous tubules
Straight seminiferous tubule

- **The seminiferous tubules:**

Remain solid until puberty when they acquire a lumen.

Their walls are composed of 2 kinds of cells:

Sertoli cells are derived from the surface epithelium of the gland.

Spermatogonia are derived from primordial germ cells.

- **Interstitial cells of Leydig:** They are derived from original mesenchyme of the gonadal ridge. They lie between the testis cords.
- **Finally,** the rete testis becomes continuous with 15 - 20 mesonephric tubules which become the efferent ductules of the testis.

B- Descent of the testis:

- Testis develops high up in the posterior abdominal wall but has to descend to lie in the scrotum.
- The descent of the testis is guided by a fibrous cord called **gubernaculum** which extends from lower pole of the testis till the floor of the scrotal pouch.
- An evagination of peritoneal sac (process vaginalis) accompanies the gubernaculum to the scrotum.
- Factors affecting the descent:

1- Shortening of the gubernaculum.

2- Hormones such as androgen and Mullerian Inhibiting Substance (MIS).

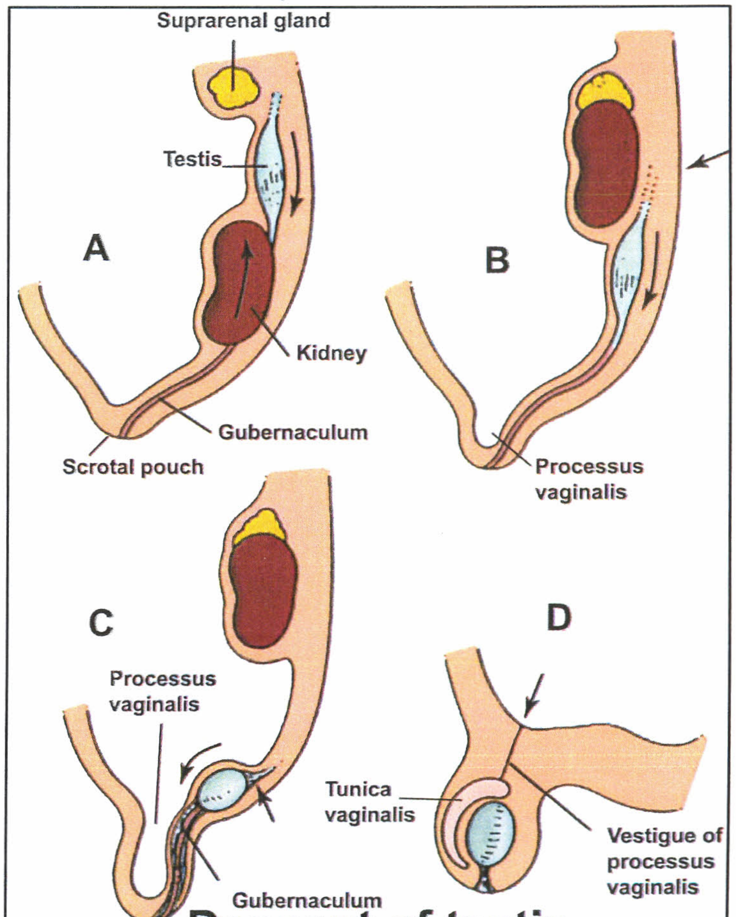
3- Increase of the intra-abdominal pressure.

- Time sequence of the testis descent:

* 3rd month --------- it reaches the iliac fossa.

* 7th month ----- traverses the inguinal canal

* 9th month ------ descends into the scrotum.



Descent of testis

- Fate of the processus vaginalis

* Proximal part------------ obliterated (vestigue of processus vaginalis).

* Distal part ------------ forms the tunica vaginalis.

C- Congenital anomalies of the testis:

A) Anomalies of formation:

1. Gonadal dysgenesis: improper formation due to failure of migration of primordial germ cells.

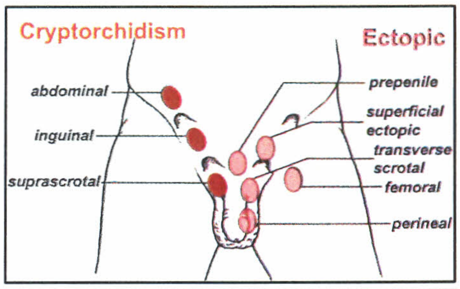
2. Klinefelter syndrome: (47, XXY): patients are characterized by infertility & gynecomastia.

3. Hermaphrodites (intersex):

True hermaphrodites: both ovarian and testicular tissue is combined and external genitalia predominantly female.

Pseudo- hermaphrodites: gonads are of testis while external genitalia are of females.

B- Anomalies of descent:

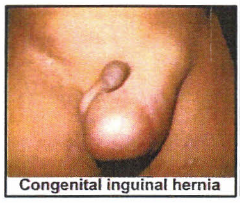

Cryptorchidism
Ectopic
abdominal
inguinal
suprascrotal
prepenile
superficial ectopic
transverse scrotal
femoral
perineal

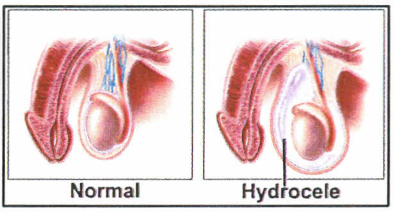
1) **Cryptorchism (undescended testis):** the testis may be arrested at the abdomen or the inguinal canal.

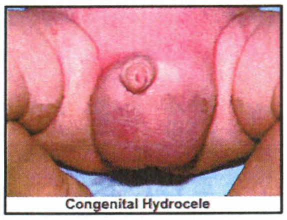
2) **Ectopic testis:** The gubernaculum may have accessory slips attached to abnormal sites e.g. root of the penis, perineum or upper part of medial side of the thigh.

C) Anomalies of processus vaginalis:

1) **Congenital hydrocele:** persistence of the whole processus vaginalis so the tunica vaginalis filled with peritoneal fluid.


Congenital inguinal hernia


Normal Hydrocele


Congenital Hydrocele

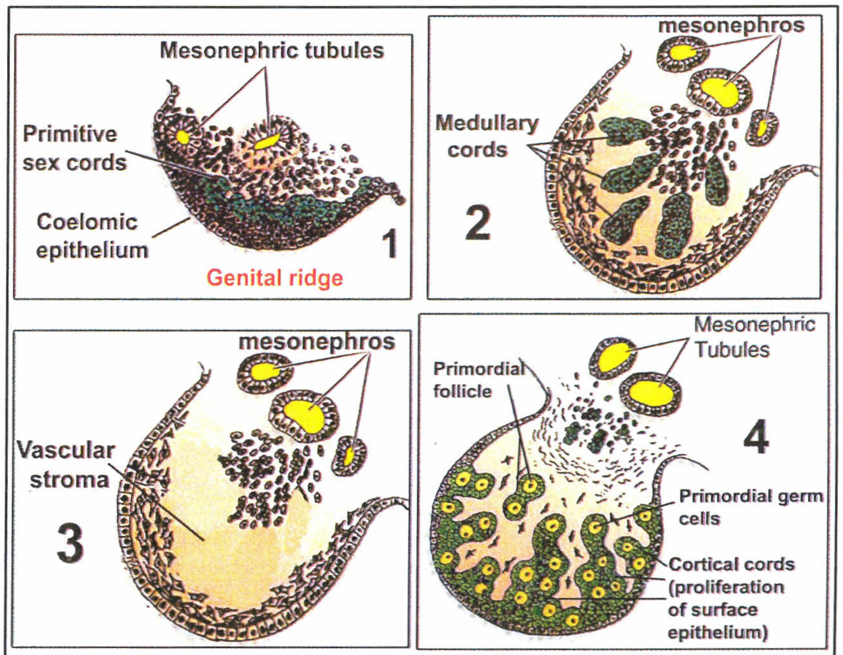
2) **Congenital inguinal hernia:**

Persistence of the whole processus vaginalis and loop of intestine herniates into it.

III) Development of the ovary:

A- Steps of ovary development:

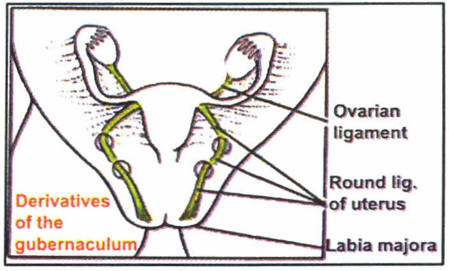
- The primitive sex cords become broken up into irregular cluster of cells. These clusters are located in the medulla of the ovary (medullary cords).
- The medullary cords disappear and are replaced by vascular stroma that forms ovarian medulla.
- The surface epithelium continues to proliferate and gives rise to 2nd generation of cords (cortical cords).
- The cortical cords are split into isolated cell clusters (primordial follicles). Each consists of oogonia (primordial germ cells) surrounded by follicular cells.


Mesonephric tubules
Primitive sex cords
Coelomic epithelium
Genital ridge
1
mesonephros
Medullary cords
2
mesonephros
Vascular stroma
3
Mesonephric Tubules
Primordial follicle
4
Primordial germ cells
Cortical cords (proliferation of surface epithelium)

Development of the ovary

B- Descent of the ovary:

- The ovary has a gubernaculum which is attached below to the labium majus.
- The ovary descends from its higher position to reach just below the inlet of the pelvis.


Ovarian ligament
Round lig. of uterus
Labia majora
Derivatives of the gubernaculum

Fate of gubernaculum:

Its cranial part ------------ forms the ligament of ovary.

Its caudal part ------------ forms the round ligament of uterus.

C- Congenital anomalies of the ovary: Gonadal dysgenesis:

In gonadal dysgenesis the oocytes are absent and the ovaries appear as streak gonads.

1- XY female gonadal dysgenesis (Swyer syndrome): results from mutation of SRY gene.

2- Turner syndrome (45, XO): have gonadal dysgenesis and short stature.

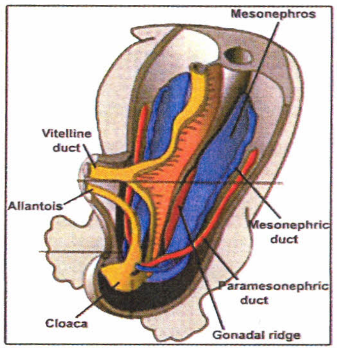
3- Female pseudo-hermaphrodites: the most common anomaly is congenital adrenal hyperplasia (adrogenital syndrome).

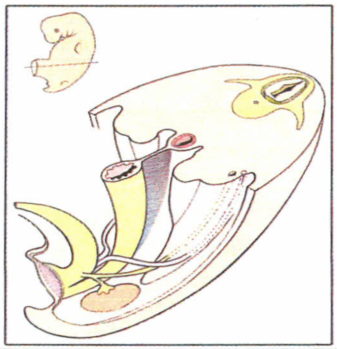
Development of Genital Ducts

A) Indifferent stage:

Initially, both male and female embryos have two pairs of genital ducts: mesonephric (Wollfian) ducts and para mesonephric (Müllerian) ducts.

Further sex differentiation depends on the sex of embryo.


Mesonephros
Vitelline duct
Allantois
Mesonephric duct
Paramesonephric duct
Cloaca
Gonadal ridge



B) Mesonephric (Wolffian) duct: See before

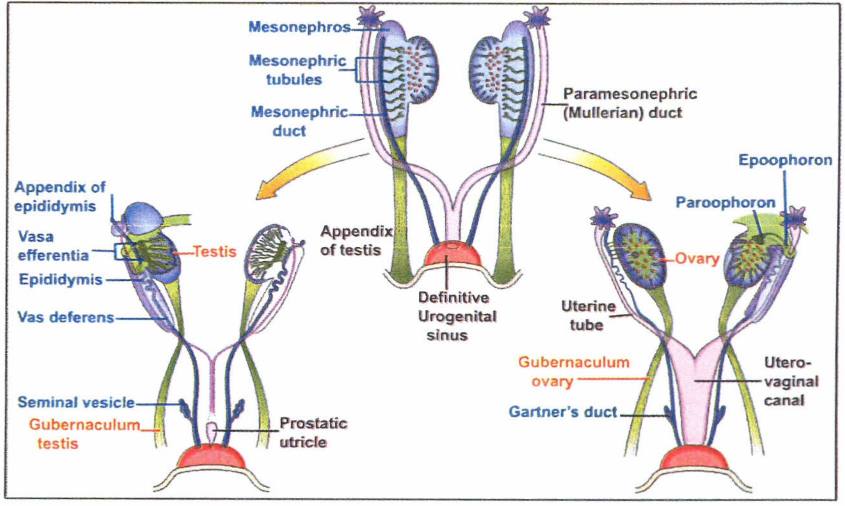
C)Paramesonephric(Müllerean)duct:

Definition: Is a longitudinal duct that descends close to mesonephric duct.

It has 2 ends:

Cranial end: opens into coelomic cavity.

Caudal end: is blind & connected to posterior wall of the definitive urogenital sinus.


Mesonephros
Mesonephric tubules
Mesonephric duct
Paramesonephric (Mullerian) duct
Epoophoron
Paroophoron
Ovary
Appendix of epididymis
Vasa efferentia
Testis
Epididymis
Appendix of testis
Vas deferens
Definitive Urogenital sinus
Uterine tube
Gubernaculum ovary
Utero-vaginal canal
Gartner's duct
Seminal vesicle
Gubernaculum testis
Prostatic utricle

Course of the duct:

Cranial part (⅓): descends vertically lateral to the mesonephric duct.

Intermediate part (⅓): passes horizontally ventral to mesonephric duct.

Caudal part (⅓): It descends vertically medial to the mesonephric duct.

The caudal vertical parts of both ducts fuse to form uterovaginal canal.

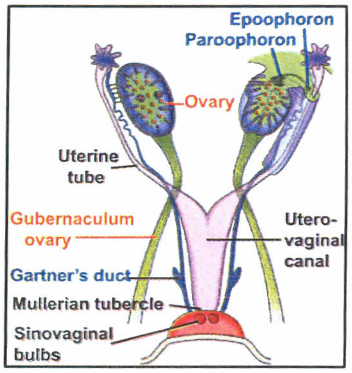
Fate of the duct:

In male: appendix of testis and prostatic utricle.

In female:

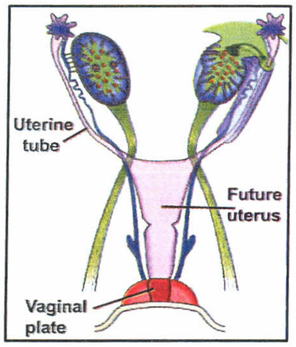
Cranial and middle parts give rise to the Fallopian tube.

Caudal ⅓ gives rise to the uterus and superior part of the vagina.

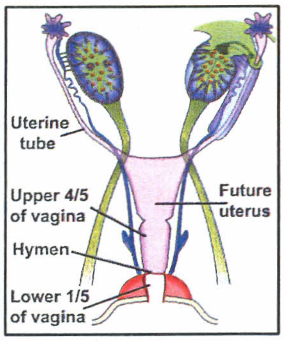

Epoophoron
Paroophoron
Ovary
Uterine tube
Gubernaculum ovary
Utero-vaginal canal
Gartner's duct
Mullerian tubercle
Sinovaginal bulbs

Development of the vagina:

- The contact of caudal end of the paramesonephric ducts with definitive urogenital sinus produce Müllerian tubercle.
- The endoderm overlying Müllerian tubercle proliferates forming 2 sinovaginal bulbs.
- The sinovaginal bulbs fuse forming vaginal plate.

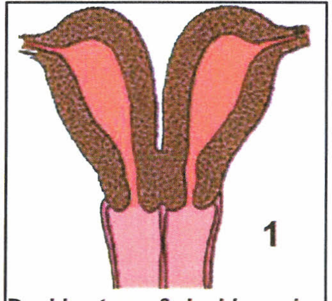

Uterine tube
Future uterus
Vaginal plate

- The central cells in the vaginal plate break down, forming the vaginal epithelium.
- So the vagina has a double origin:
  - **The** upper part is from uterine cavity (para mesonephric duct).
  - **The** lower part derived from the urogenital sinus (endodermal).
- The lumen of the upper vagina is separated from the cavity of urogenital sinus by the **hymen.**

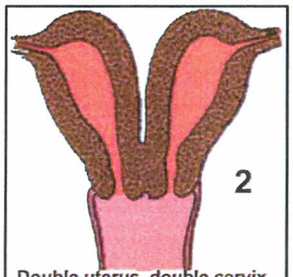


Congenital anomalies of the female genital ducts:

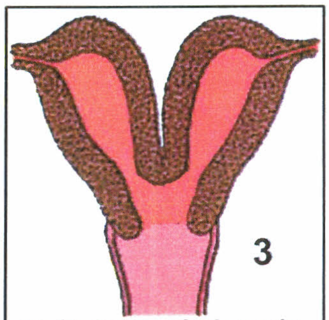
A- Anomalies due to failure of fusion of 2 paramesonephric ducts:



Double uterus & double vagina



Double uterus, double cervix and single vagina



Double uterus, single cervix & single vagina

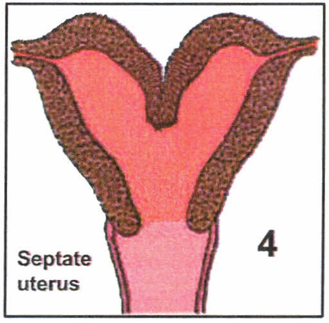
1- Double uterus and double vagina: due to complete failure of fusion of the 2 ducts .

2- Double uterus, double cervix & single vagina (bicornis bicollis): due to incomplete fusion of the 2 ducts.

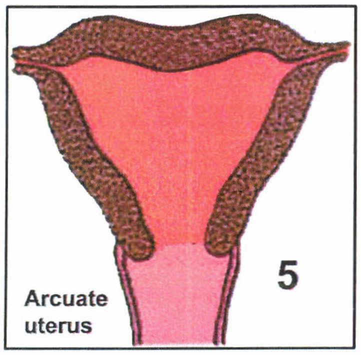
3- Double uterus, single cervix and single vagina (bicornis unicollis): due to partial failure of fusion of the 2 ducts.

4- Septate uterus: a small septum remains in the upper part of the uterine cavity.

5- Arcuate uterus: fundus is depressed due to minor degree of imperfect fusion of the 2 ducts.



Septate uterus



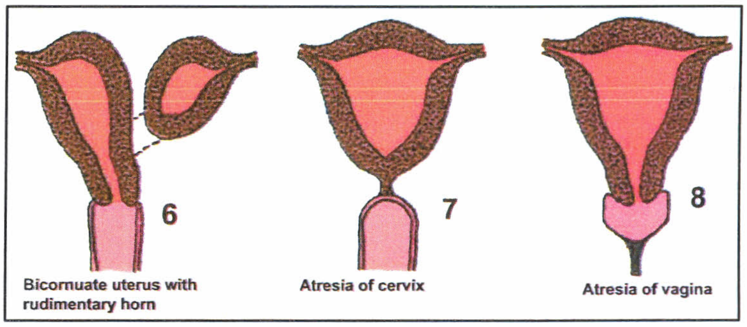
Arcuate uterus

B- Anomalies due to complete or partial atresia of paramesonephric ducts:

6- Bicornuate uterus with a rudimentary horn: one paramesonephric duct retard in growth.

7- Atresia of cervix: due to failure of canalization of the cervical canal.

8- Atresia of vagina: due to failure of canalization of the vaginal plate.



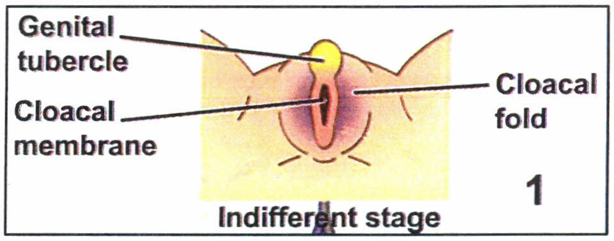
Bicornuate uterus with rudimentary horn
Atresia of cervix
Atresia of vagina

9- Imperforate hymen: due to failure of perforation of the inferior end of the vaginal plate.

Development of External Genitalia

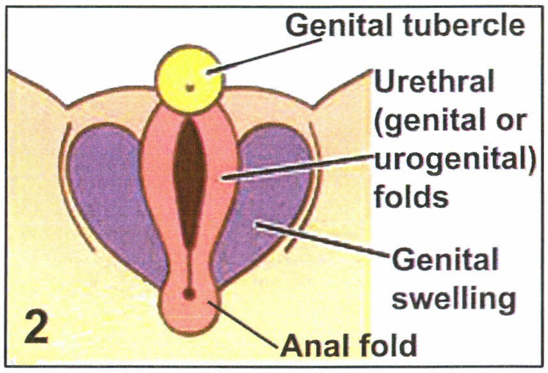
A- Indifferent stage:

- Mesenchyme cells originating in the region of the primitive streak migrate around the cloacal membrane to form a pair of cloacal folds.



Indifferent stage

- Cranial to the cloacal membrane the folds unite to form the genital tubercle.
- Later on, the folds are subdivided into:
  * Urethral folds (genital or urogenital folds) anteriorly.
  * Anal folds posteriorly.
- Another pair of elevations, genital swellings, becomes visible on each side of urethral folds.

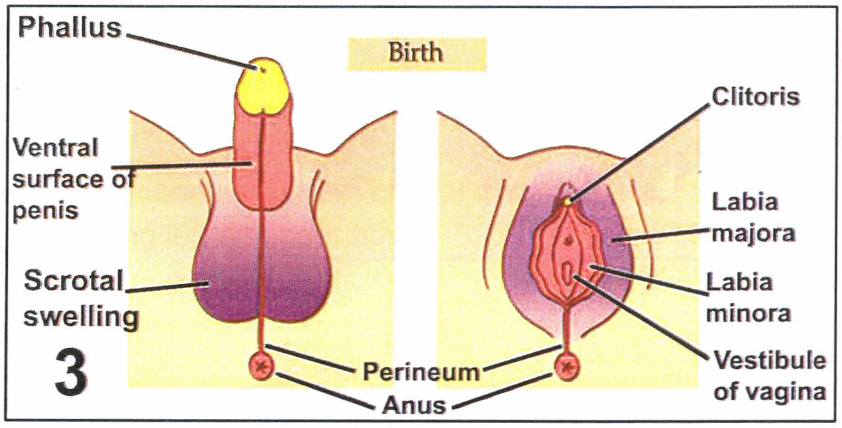

2
Genital tubercle
Urethral (genital or urogenital) folds
Genital swelling
Anal fold

B- External genitalia in the male:

- The **genital tubercle** elongates to form the phallus.
- The phallus pulls the urethral folds so that they form the lateral walls of the urethral groove.
- The **fusion of the urethral folds** forms the ventral surface of the penis.
- The **genital swellings** form the scrotal swellings.

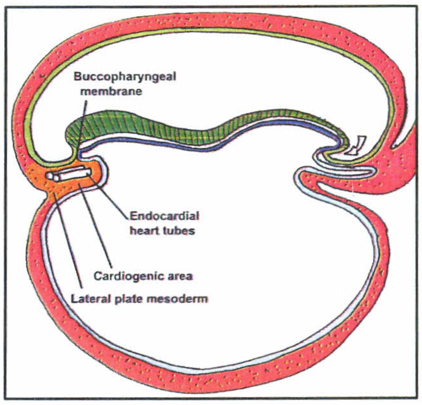
B- External genitalia in the female:

- The **genital tubercle** elongates slightly and forms the clitoris.
- The **genital folds** do not fuse, as in the male, but develop into the labia minora.
- The **genital swellings** enlarge and form the labia majora.
- The **urogenital groove** is open and forms the vestibule of the vagina.


3
Phallus
Birth
Ventral surface of penis
Scrotal swelling
Perineum
Anus
Clitoris
Labia majora
Labia minora
Vestibule of vagina

Development of the heart

1- Establishment of the cardiogenic field:


Buccopharyngeal membrane
Endocardial heart tubes
Cardiogenic area
Lateral plate mesoderm

- The vascular system appears in the middle of the 3rd week.
- Cardiac area develops in lateral plate mesoderm (cranial to bucccopharyngeal membrane).
- Then, a pair of the endocardial tubes begins to develop in the cardiogenic region.
- Later, the two endocardial tubes meet and fuse to form a single primary heart tube.
- The outflow to the heart tube:

A paired dorsal aortae form simultaneously with the endocardial heart tubes. They are connected cranially with the endocardial tubes.

- The inflow to the heart tube: is supplied by three pairs of vessels:

a) A pair of common cardinal veins drain blood from the body of the embryo.

b) A pair of vitelline veins drains the yolk sac.

c) A pair of umbilical veins carries oxygenated blood from the placenta.

2- A series of constrictions appear in the 1^{ry} heart tube:

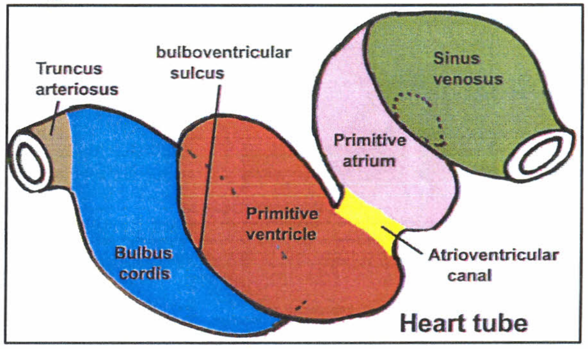
- They subdivide the heart tube into the four heart chambers (from cranial to caudal:

* Sinus venosus: consists of a central part receiving left and right horns.

* Primitive atrium.

* Primitive ventricle is separated from the atrium by the atrioventricular canal.

* Bulbus cordis, is separated from the ventricle by the bulboventricular sulcus.


Truncus arteriosus
bulboventricular sulcus
Sinus venosus
Primitive atrium
Primitive ventricle
Bulbus cordis
Atrioventricular canal
Heart tube

3- Formation of the cardiac loop:

The heart tube begins to elongate and simultaneously to loop and fold.

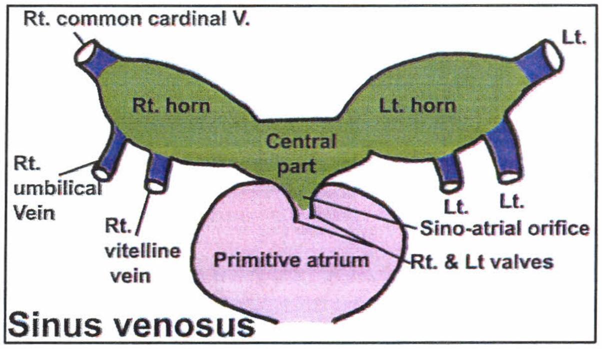
* The bulbus cordis is displaced inferiorly, ventrally, and to the right

* The primitive ventricle is displaced to the left.

* The primitive atrium is displaced posteriorly and superiorly.

Sinus venosus

Definition: It is the most caudal part of the heart tube. It receives all veins of the body.


Rt. common cardinal V.
Lt.
Rt. horn
Lt. horn
Central part
Rt. umbilical Vein
Rt. vitelline vein
Lt.
Lt.
Sino-atrial orifice
Rt. & Lt valves
Primitive atrium
Sinus venosus

Structure:

It is formed of a small median part and two lateral horns (Rt and Lt).

Each horn receives:

a) Vitelline vein: from yolk sac.

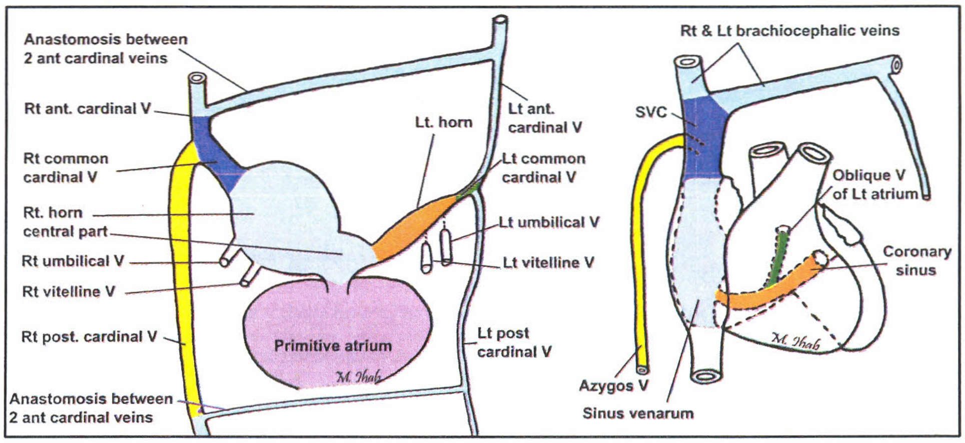
b) Umbilical vein: from the placenta.

c) Common cardinal vein: from the body of the embryo itself.

It opens into to the primitive atrium by a sino-atrial orifice guarded by Rt and Lt valves.

Fate of the sinus venosus:

1- The left sinus horn: diminishes in size due to:


Anastomosis between
2 ant cardinal veins
Rt ant. cardinal V
Rt common cardinal V
Rt. horn
central part
Rt umbilical V
Rt vitelline V
Rt post. cardinal V
Anastomosis between
2 ant cardinal veins
Primitive atrium
M. Ihab
Lt. horn
Lt ant. cardinal V
Lt common cardinal V
Lt umbilical V
Lt vitelline V
Lt post cardinal V
Rt & Lt brachiocephalic veins
SVC
Oblique V of Lt atrium
Coronary sinus
Azygos V
Sinus venarum
M. Ihab

a- Lt vitelline and Lt umbilical veins lose their connection with the sinus venosus.

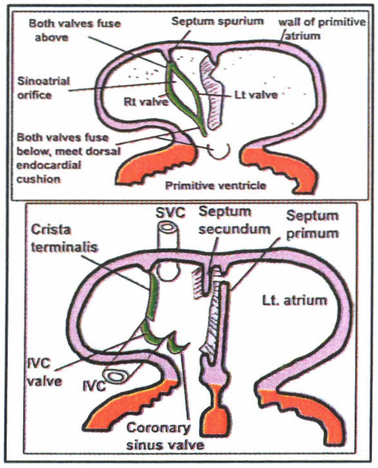
b- Shift of venous blood to the Rt side due to development of transverse anastomoses between the 2 anterior cardinal veins and 2 posterior cardinal veins.

The left sinus horn becomes smaller and forms coronary sinus.

The left common cardinal vein forms the oblique vein of Lt atrium.

2- The right sinus horn and median part: become absorbed into the Rt. side of the primitive common atrium and will form the sinus venarum (the posterior part of Rt atrium).

The right common cardinal vein forms the lower part of S.V.C.


Both valves fuse above
Septum spurium
wall of primitive atrium
Sinoatrial orifice
Rt valve
Lt valve
Both valves fuse below, meet dorsal endocardial cushion
Primitive ventricle
Crista terminalis
SVC
Septum secundum
Septum primum
Lt. atrium
IVC valve
IVC
Coronary sinus valve

3- Rt & Lt valves of the sino-atrial orifice:

- These are 2 folds which appear at the sino-atrial orifice. They fuse cranially to form the Septum spurium which forms the upper part of the crista terminalis.
- The sino-atrial orifice has 2 valves:

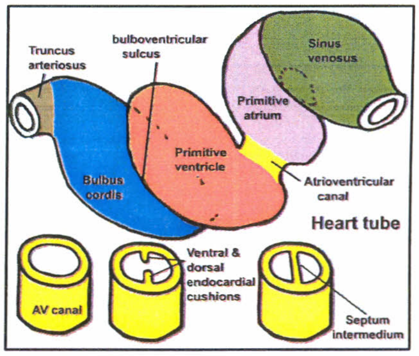
* Lt valve fuses with interatrial septum

* Rt valve: Its upper part → lower part of the crista terminalis.

Its lower part → valves of IVC & coronary sinus.

Development of the atria

1- Development of the interatrial septum


Truncus arteriosus
bulboventricular sulcus
Sinus venosus
Primitive atrium
Primitive ventricle
Bulbus cordis
Atrioventricular canal
Heart tube
AV canal
Ventral & dorsal endocardial cushions
Septum intermedium

The interatrial septum develops from 3 sources:

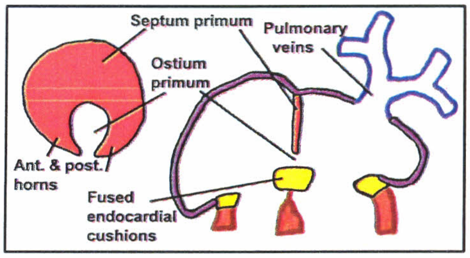
a) Septum intermedium in the atrioventricular (AV) canal

- Ventral & dorsal endocardial cushions appear in walls of A-V canal.
- The 2 cushions approach each other and fuse forming septum intermedium. It divides the A-V canal into 2 halves (Rt & Lt).

b) Septum primum

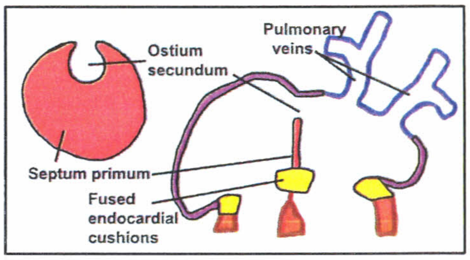
Shape: Sickle-shaped having lowered crescentic border ending in ventral and dorsal horns.

Origin and course: it arises from roof of the common atrium and descends in direction of endocardial cushions of the A-V canal.


Septum primum
Pulmonary veins
Ostium primum
Ant. & post. horns
Fused endocardial cushions

Fate:

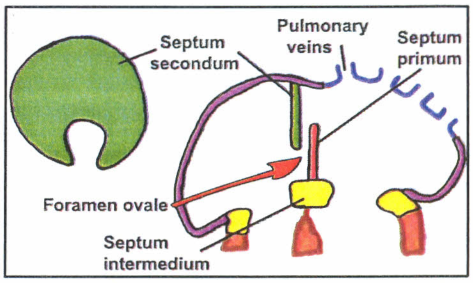
- The septum primum divides the cavity of the primitive atrium incompletely into Rt. and Lt. halves.
- The lower border of the septum is still separated from the endocardial cushions by a gab is called the ostium primum.



- As development proceeds, ostium primum becomes obliterated.
- A second foramen called ostium secundum appears as a result of breaking down of the cephalic part of the septum primum.

c) Septum Secundum

Shape: Sickle-shaped having a lower crescentic edge with 2 horns (ventral and dorsal).

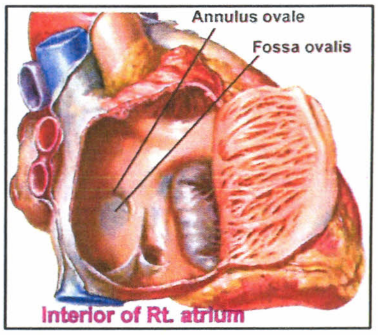


Origin and course:

- It arises from the roof of the common atrium (on the Rt. side of the septum primum).
- It descends caudally in the direction of the septum intermedium until its 2 horns fuse with it.

Fate:

- The septum secundum overlaps the ostium secundum. Its caudal edge is still separated from the upper edge of the septum primum by a gab is called the foramen ovale.
- The foramen ovale closes at birth due to firm apposition and fusion between septum primum & secundum to form the interatrial septum.



Interior of Rt. atrium

Embryological remnants of the two fetal septa in the adult heart

Fossa ovalis: represents the lower part of the septum primum.

Annulus ovale: represents free caudal edge of the septum secundum.

2- Absorption of the A-V canals in to the atria

Each of the Rt. and Lt. A-V canals becomes absorbed into the corresponding atrium.

3- Absorption of the pulmonary vein into the left atrium:

- At first, a single pulmonary vein opens into the dorsal wall of the Lt. atrium.
- This single vein is formed by the union of Rt and Lt vein, each of which is formed by 2 veins emerging from the lung.
- Later on, the stem of the common pulmonary vein and its 2 tributaries become absorbed into the wall of the Lt. atrium.
- Thus the 4 pulmonary veins open separately into the Lt. atrium.

Embryological components of each atrium

	Components of the Rt atrium	Components of the Lt atrium
1	The Rt ½ of the common atrium. It forms the rough anterior part + the auricle.	The Lt ½ of the common atrium. It forms the Lt. auricle.
2	Absorbed Rt AV canal.	Absorbed Lt A-V canal.
3	Absorbed sinus venosus.	Absorbed pulmonary vein & its tributaries.

Anomalies of the interatrial septum

1- Premature closure of foramen ovale:

Character: premature closure of foramen ovale in the intrauterine life.

Results: hypertrophy of Rt atrium and Rt ventricle with underdevelopment of Lt ventricle. It leads to the death shortly after birth.

2- Probe patent foramen ovale:

Normally, the foramen ovale closes completely at birth.

In 20 - 25 % of people, a probe can be passed through the foramen ovale.

3- Ostium secundum defect:

Character: there is a large opening between the 2 atria.

Cause: it is due to either:

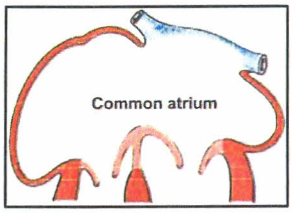
-Excessive resorption of septum primum.

-Improper formation of septum secundum.

4- Complete failure of formation of the interatrial septum:

The heart is formed of 3 chambers (common atrium & 2 ventricles).

Cause: it is due to failure of septation of the primitive atrium.

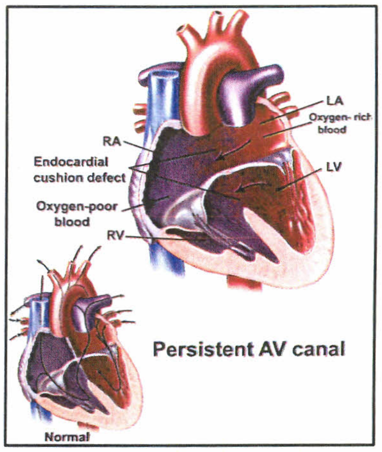

Common atrium

Anomalies of the atrioventricular canal

1- Persistent A-V canal:

It is usually accompanied by atrial & ventricular septal defect.

Cause: complete failure of fusion of the ventral and dorsal endocardial cushions.


LA
Oxygen- rich blood
RA
Endocardial cushion defect
LV
Oxygen-poor blood
RV
Persistent AV canal
Normal

2 - Ostium primum defect:

Cause: partial (incomplete) fusion of the ventral and dorsal endocardial cushions.

So, septum primum fails to join the septum intermdium → failure of closure of the ostium primum.

3- Tricuspid atresia:

Cause: fusion of cusps of the tricuspid valve leading to its absence.

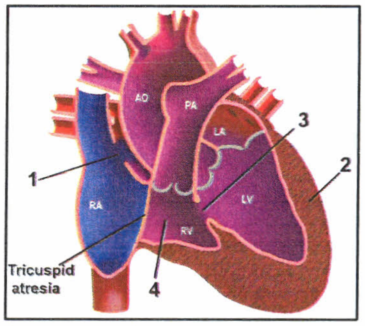
It is usually accompanied by:

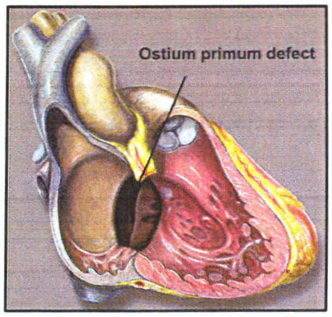
1- Patent foramen ovale.

2- Hypertrophy of Lt. ventricle.

3- Patent interventricular foramen

4- Under development of Rt ventricle.


AO
PA
LA
3
1
RA
LV
2
RV
Tricuspid atresia
4

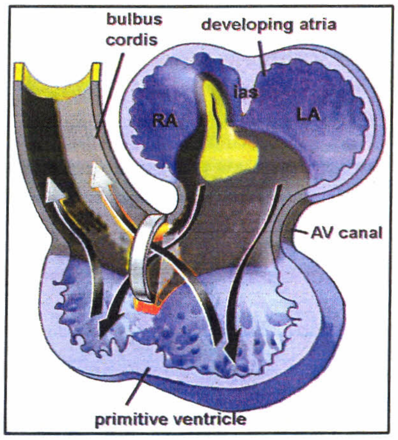

Ostium primum defect

Development of the ventricles

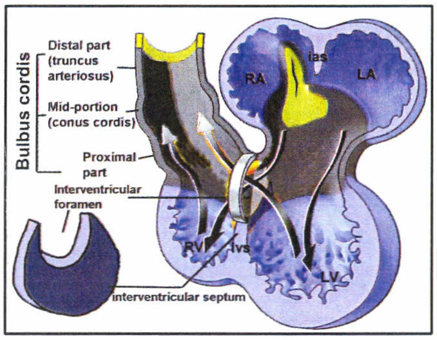
1- Formation of the interventricular septum

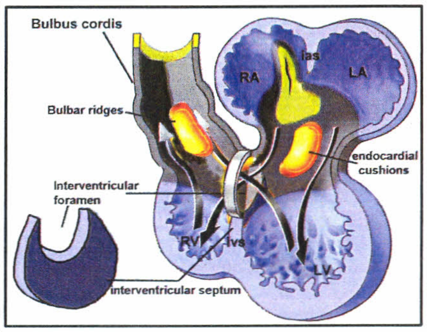
A) Development of muscular part of the interventricular (IV) septum

- The medial walls of the enlarging ventricles approach each other and fuse to form the primordium of the muscular part of the IV septum.
- This septum is crescentic in shape and has a concave free edge.
- Most of its increase in height results from:
  - * Dilation of the ventricles on each side of the septum.
  - * Active proliferation of myoblasts in the septum.


bulbus cordis
developing atria
ias
RA
LA
AV canal
primitive ventricle

- There is a crescent-shaped interventricular foramen between the free edge of the IV septum & fused endocardial cushions.


Bulbus cordis
Distal part (truncus arteriosus)
Mid-portion (conus cordis)
Proximal part
Interventricular foramen
RA
LA
ias
RV
ivs
LV
interventricular septum


Bulbus cordis
Bulbar ridges
RA
LA
ias
endocardial cushions
Interventricular foramen
RV
ivs
LV
interventricular septum

B) Development of the membranous part of the interventricular septum:

- This part develops by end of 7th week to close the I.V foramen.
- It is formed of 2 components:
  1- Outgrowth of atrioventricular endocardial cushions.
  2- Lower part of the conus septum (Rt and Lt bulbar ridges).

2- Absorption of midportion (conus cordis) of bulbus cordis:

- Conus cordis is absorbed into the ventricles forming the outflow tracts of both ventricles:
  * The part absorbed into the Rt ventricle will form the infundibulum.
  * The part absorbed into the Lt ventricle will form the vestibule of the aorta.

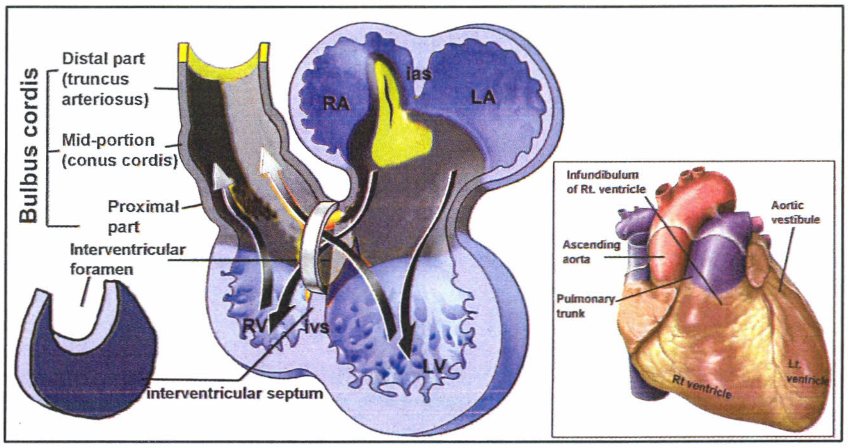
3- Sources of the ventricles

Primitive ventricle: It gives rise to

* Most of the left ventricle.
* Inlet region of the Rt ventricle.

Bulbus cordis:

* The proximal part will form most of the right ventricle.
* The midportion part (conus cordis) forms the outflow tracts of both ventricles.


Bulbus cordis
Distal part (truncus arteriosus)
Mid-portion (conus cordis)
Proximal part
Interventricular foramen
RA
LA
ias
RV
ivs
LV
interventricular septum
Infundibulum of Rt. ventricle
Aortic vestibule
Ascending aorta
Pulmonary trunk
Rt ventricle
Lt. ventricle

Anomalies of the interventricular septum (ventricular septal defects)

- A defect in the membranous part of the IV septum.
- A defect in the membranous as well as the muscular part of the IV septum.
- The whole IV septum may be absent.

Bulbus Cordis

1- Parts of the bulbus cordis:

i) The proximal part: will form most of the Rt ventricle.

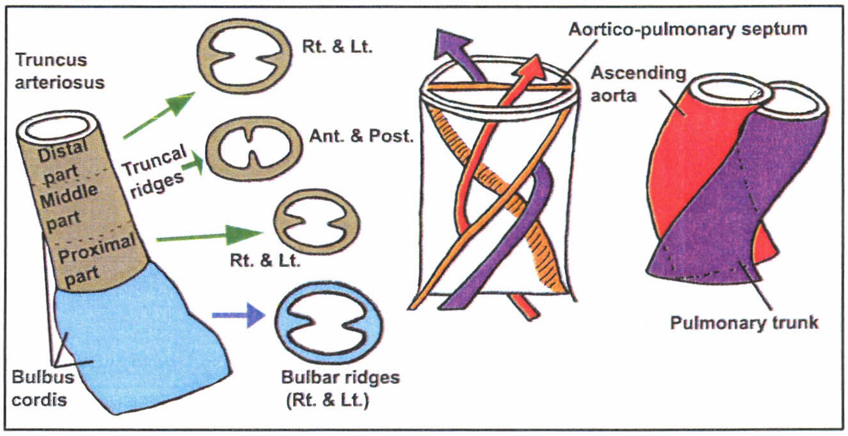
ii) The mid-portion part (conus cordis): is absorbed into the ventricles forming the outflow tracts of both ventricles.

ii) The distal part (truncus arteriosus): It is divided by the spiral aortico-pulmonary septum into roots and proximal portions of the ascending aorta and pulmonary trunk.

2- Formation of the aortico-pulmonary septum:

- During the 5th week, 2 (Rt & Lt) bulbar and truncal ridges are developed. They are derived from neural crest mesenchyme.

- They are bulbar (in bulbus cordis) & truncal (in truncus arteriosus). They are continuous with each other.
- These 2 ridges grow down towards the ventricles in a spiral way so that:
  - * They become anterior and posterior in middle part of the truncus.
  - * Then, they become Rt and Lt again in the proximal part (near the ventricles).
- By the 8th week, the 2 ridges become fused to form a spiral aortico-pulmonary septum dividing the truncus arteriosus into pulmonary trunk and ascending aorta.


Truncus arteriosus
Rt. & Lt.
Distal part
Middle part
Truncal ridges
Ant. & Post.
Proximal part
Rt. & Lt.
Bulbus cordis
Bulbar ridges (Rt. & Lt.)
Aortico-pulmonary septum
Ascending aorta
Pulmonary trunk

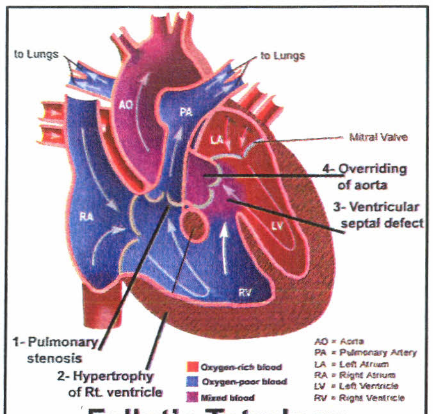
- The spiral course of the aortico-pulmonary septum explains:
  1- Adult relations between the ascending aorta and pulmonary trunk; the pulmonary trunk lies anterior then to the left and finally posterior to the ascending aorta.
  2- The 2 arteries are enclosed in a common tube of visceral pericardium.

Anomalies of the bulbus cordis:

1- Fallot's tetralogy:

Characters: 1- Pulmonary stenosis. 2- Hypertrophy of Rt ventricle.
3- Ventricular septal defect.
4- Overriding aorta i.e. the mouth of aorta receives blood from both ventricles.

Cause: anterior displacement of the aortico-pulmonary septum leads to unequal division of the conus.

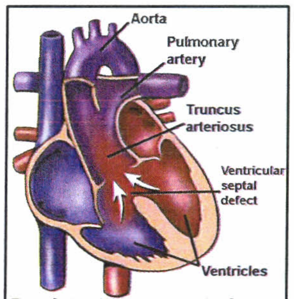

to Lungs
to Lungs
AO
PA
LA
Mitral Valve
4- Overriding of aorta
3- Ventricular septal defect
RA
LV
RV
1- Pulmonary stenosis
2- Hypertrophy of Rt. ventricle
Oxygen-rich blood
Oxygen-poor blood
Mixed blood
AO = Aorta
PA = Pulmonary Artery
LA = Left Atrium
RA = Right Atrium
LV = Left Ventricle
RV = Right Ventricle

Fallot's Tetralogy

2- Persistent truncus arteriosus:

Cause: failure of the 2 bulbar cushions to form the aortico-pulmonary septum.

It is accompanied by: membranous ventricular septal defect.


Aorta
Pulmonary artery
Truncus arteriosus
Ventricular septal defect
Ventricles

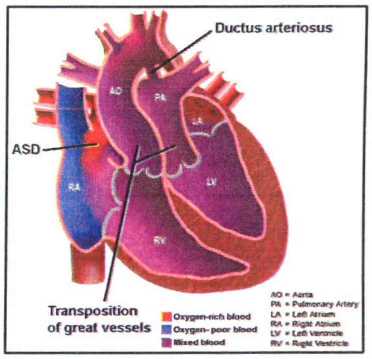
Persistent truncus arteriosus

3- Transposition of the Great Arteries (TGA):

Cause: Aortico-pulmonary septum runs a straight course instead of its normal spiral course.

It leads to:

- * Aorta is connected below with the Rt. ventricle.
- * Pulmonary trunk is connected below with the Lt. ventricle.


Ductus arteriosus
AO
PA
LA
ASD
RA
LV
RV
Transposition of great vessels
Oxygen-rich blood
Oxygen-poor blood
Mixed blood
AO = Aorta
PA = Pulmonary Artery
LA = Left Atrium
RA = Right Atrium
LV = Left Ventricle
RV = Right Ventricle

Development of the cardiac valves

The semilunar valves develop from three swellings of subendocardial tissue around the orifices of the aorta and pulmonary trunk.

These swellings are hollowed out and reshaped to form three thin-walled cusps.

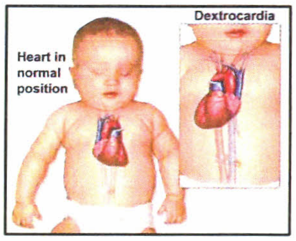
The atrioventricular (A-V) valves (tricuspid and mitral valves) develop similarly from localized proliferations of tissue around the A-Y canals.

Anomalies of semilunar valves:

1- **Pulmonary stenosis:** is due to fusion the cusp of the pulmonary valve.

2- **Aortic stenosis:** is due to fusion of the cusps of the aortic valve.

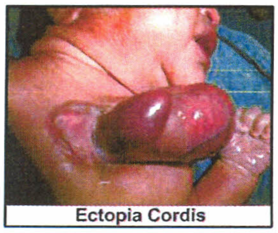
Anomalies of position of the heart:



1- Dextrocardia:

The heart and its great vessels lie as a mirror image to their normal position.

This may occur alone or may be associated with reversal of all organs (situs inversus totalis).


Ectopia Cordis

2- Ectopia cordis:

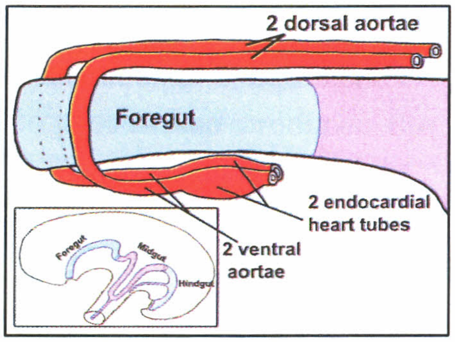
The heart is exposed to surface of the thorax through a defect in sternum.

It is due to failure of the embryo to close in the middle line.

Development of the arteries

Differentiation of the 2 primitive aortae

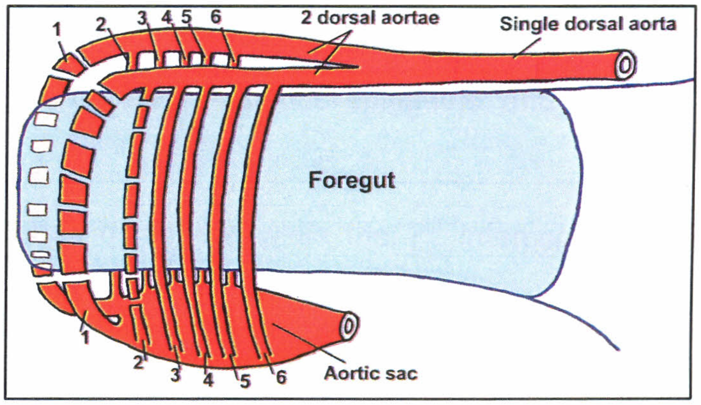
I- Rt and Lt primitive aortae and the 2 dorsal aortae:



- The first intra-embryonic arteries to appear are the Rt and Lt primitive ventral aortae, which appear as continuation of the two endocardial heart tubes.
- They lie ventral to the foregut.
- From this site they curve dorsally and continue caudally as two dorsal aortae.

II- Aortic sac and the common dorsal aorta

- As the 2 endocardial tubes fuse with each other to form the single heart, the 2 primitive (ventral) aortae also fuse to form the aortic sac.
- As pharyngeal arches develop, the aortic sac sends a branch to each pharyngeal arch (6 pairs of aortic arches). The aortic arches curve beyond the pharyngeal gut and join the 2 dorsal aortae.
- Caudally, beyond the level of the 6th aortic arches the 2 dorsal aortae approach each other and finally fuse forming a single dorsal aorta.



Dorsal Aorta

1- Fate of dorsal aortae:

The segment	Rt:	Lt:
Cranial to 3rd aortic arch	Forms the distal part of the I.C.A.	
Between the 3rd and 4th aortic arch (Ductus caroticus)	Disappears.	
Between 4th aortic arch & 7th inter-segmental artery	Forms part of the Rt subclavian artery.	Forms the distal part of arch of aorta.
Caudal to 7th inter-segmental artery & common dorsal aorta	Disappears	

2- Branches of the dorsal aorta:

A- Ventral splanchnic (vitelline) arteries:

1 - Coeliac artery: the most cranial and supplies the foregut.

2 - Superior mesenteric artery: the middle and supplies the midgut.

3 - Inferior mesenteric artery: the most caudal and supplies the hindgut.

B- Lateral splanchnic arteries:

1 - Renal arteries.

2 - Testicular or ovarian arteries.

3 - Middle suprarenal arteries.

4 - Inferior phrenic arteries.

C- Somatic (intersegmental) arteries:

They run in the cervical, thoracic and lumbar regions between the somites.

Each artery divides into a small dorsal and a large ventral branches.

The dorsal branches of the intersegmental arteries:

They are well developed in the cervical region, where they form two longitudinal anastomoses:

* Post transverse anastomosis lies posterior to the transverse processes and produces the deep cervical artery.

* Post costal anastomosis lies anterior to the transverse processes and produces the vertebral artery.

The ventral branches of the intersegmental arteries:

They are well developed in thoracic & lumbar regions. They form two longitudinal anastomoses:

* Pre-costal anastomosis gives rise to costocervical trunk, thyrocervical trunk & ascending cervical artery.

* Ventral anastomosis gives rise to the internal thoracic, superior epigastric and inferior epigastric arteries.

Fate of the intersegmental arteries:

In cervical region: most of intersegmental arteries disappear while the 7th intersegmental artery forms:

* On right side: The lower part of the right subclavian artery.

* On left side: The whole left subclavian artery.

In the thorax: persist as posterior intercostal and subcostal arteries.

In the abdomen: persist as lumbar arteries, while the 5th lumbar becomes common iliac artery and external iliac artery.

In the sacral region: persist as lateral sacral arteries.

D- Terminal (umbilical) arteries:

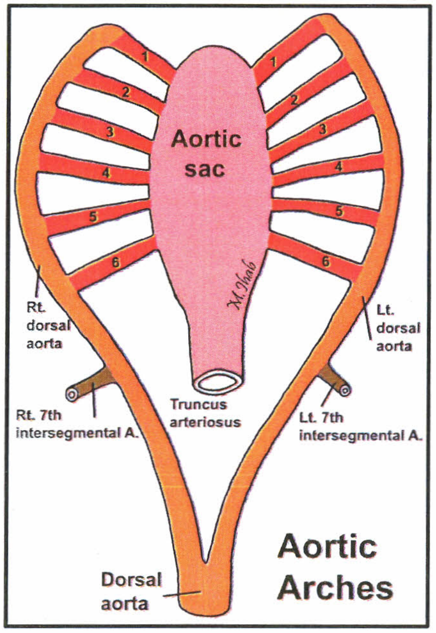
- The umbilical arteries initially paired ventral branches of the dorsal aorta.
- Each artery acquires a secondary connection with the dorsal branch of the aorta (common iliac artery) and loses its earliest origin.
- After birth, the proximal portions of the umbilical arteries persist as the obliterated umbilical arteries and the distal parts are obliterated to form the lateral umbilical ligaments.

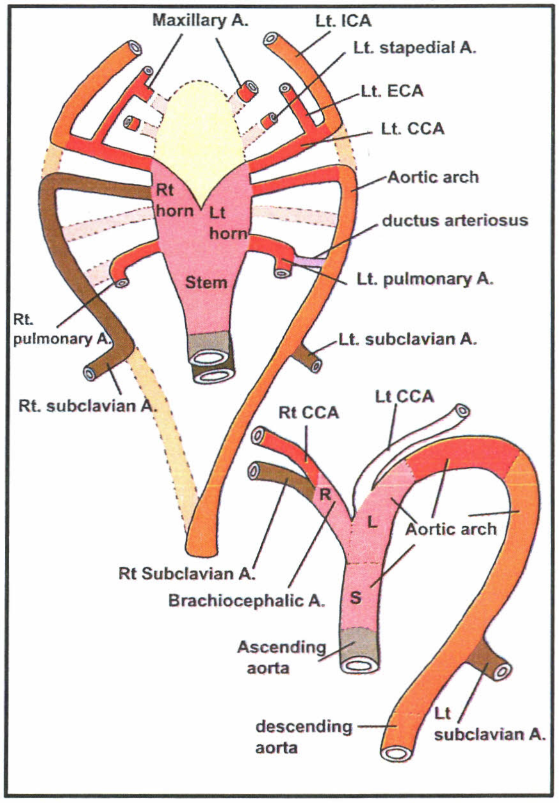
Aortic arches

They are 6 pairs of arteries; connect the aortic sac ventrally with the 2 dorsal aortae dorsally.

Formation:

- As the pharyngeal arches begin to develop, the aortic sac sends a branch to each pharyngeal arch giving rise to 6 pairs of arteries.
- Each branch leaves the aortic sac, curves around the pharynx (inside the corresponding pharyngeal arch) to end in the dorsal aorta.
- There are 6 pairs of aortic arches but they are never present at the same time; actually by the time the 3rd pair becomes completely developed the 1st pair disappears.


1
2
3
4
5
6
1
2
3
4
5
6
Aortic sac
Rt. dorsal aorta
Lt. dorsal aorta
Rt. 7th intersegmental A.
Truncus arteriosus
Lt. 7th intersegmental A.
Dorsal aorta
Aortic Arches


Maxillary A.
Lt. ICA
Lt. stapedial A.
Lt. ECA
Lt. CCA
Aortic arch
ductus arteriosus
Rt horn
Lt horn
Stem
Lt. pulmonary A.
Rt. pulmonary A.
Lt. subclavian A.
Rt. subclavian A.
Rt CCA
Lt CCA
R
L
Aortic arch
S
Rt Subclavian A.
Brachiocephalic A.
Ascending aorta
descending aorta
Lt subclavian A.

Fate of the aortic arches: The aortic arches undergo the following changes:

Aortic arch	Right		Left
1st	Disappears expect for a small part which forms the maxillary artery.		
2nd	Forms the hyoid and stapedial artery.		
3rd	Forms the C.C.A. and proximal part of the I.C.A. N.B.: the E.C.A. arises as a bud from the 3rd arch.		
4th	Forms proximal part of Rt subclavian artery.		Forms the proximal part of the arch of aorta.
5th	Disappears completely.		
6th	Ventral part	Forms Rt pulmonary artery.	Forms the Lt pulmonary artery.
	Dorsal part	Disappears.	Persists forming the ductus arteriosus which connects Lt pulmonary A. & arch of aorta.

Development of the arch of aorta

The arch of aorta develops from 4 sources as follow:

Its proximal part: (proximal to origin of brachiocephalic A.): arises from the stem of aortic sac.

Its middle part: (between brachiocephalic A. & Lt C.C.A.): arises from the Lt limb of aortic sac.

Its distal part: (distal to Lt C.C.A.): arises from 2 sources:

* The Lt 4th aortic arch.

* The lower part of the Lt dorsal aorta down the 7th inter-segmental artery.

Fate of aortic sac

The proximal part of the sac: becomes divided by the aortico-pulmonary septum so:

* The pulmonary trunk continues with the 6th aortic arches.

* The ascending aorta continues with the 3rd and 4th aortic arches.

The distal part of the sac: is elongated and splits into Right and Left Limbs:

* The Rt limb forms the innominate artery.

* The stem and Lt. limb form the proximal part of the arch of aorta.

NB: The difference of the course of Rt & Lt recurrent laryngeal nerves:

- Initially, these nerves, supply the 6th pharyngeal arches.
- When the heart descends, they hook around the 6th aortic arches and ascend again to the larynx.
- On the right, the 5th & dorsal part of the 6th aortic arches disappear. The recurrent laryngeal nerve hooks around the right subclavian artery.
- On the left, the nerve does not move up, since the dorsal part of the sixth aortic arch persists as the ductus arteriosus, which later forms the ligamentum arteriosus.

Arterial system defects

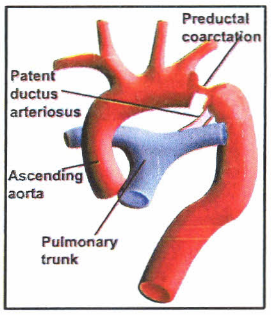
1) Coarctation of the aorta:

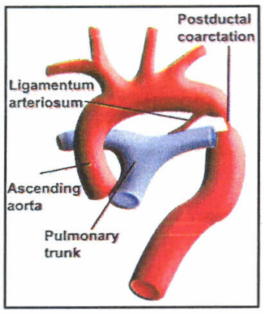
It is narrowing of aorta below origin of Lt subclavian artery.

It is of 2 types:

a. Pre-ductal type: if narrowing is above ductus arteriosus.

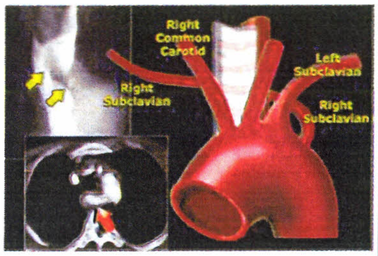
b. Post-ductal type: if the narrowing is below the ductus arteriosus.

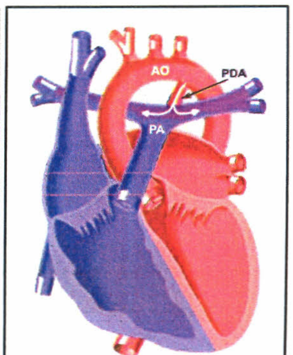

Preductal coarctation
Patent ductus arteriosus
Ascending aorta
Pulmonary trunk


Postductal coarctation
Ligamentum arteriosum
Ascending aorta
Pulmonary trunk

2) Patent ductus arteriosus:

- Normally, ductus arteriosus is closed by contraction of its muscular wall shortly after birth and within 1-3 months fibrosis of the duct is complete.
- If this closure does not occur, shunt between arch of aorta and Lt pulmonary artery occurs.


Right Common Carotid
Right Subclavian
Left Subclavian
Right Subclavian

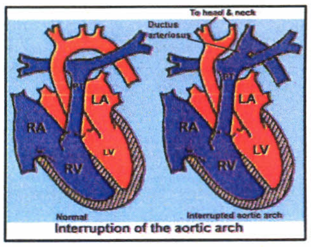


Patent ductus arteriosus

3) Abnormal origin of Rt subclavian A: The Rt subclavian is formed from Rt 7th intersegmental artery & distal segment of the Rt dorsal aorta.

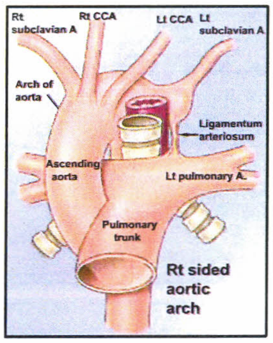
4) An interrupted aortic arch:

- It is caused by obliteration of the 4th aortic arch on the left side.
- The aorta supplies the head.
- The pulmonary trunk by the way of the ductus arteriosus supplies the rest of the body.


To head & neck
Ductus arteriosus
PT
LA
RA
LV
RV
PT
LA
RA
LV
RV
Normal
Interrupted aortic arch

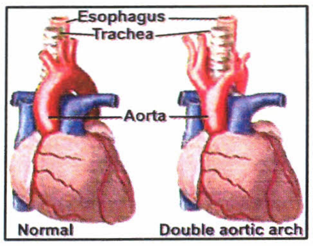
Interruption of the aortic arch

5) Rt sided aortic arch: Results from persistence of the distal part of Rt dorsal aorta and degeneration of the distal part of Lt dorsal aorta.


Rt subclavian A
Rt CCA
Lt CCA
Lt subclavian A
Arch of aorta
Ligamentum arteriosum
Ascending aorta
Lt pulmonary A.
Pulmonary trunk

Rt sided aortic arch

6) Double aortic arch: results from persistence of distal parts of Rt and Lt dorsal aortae


Esophagus
Trachea
Aorta
Normal
Double aortic arch

non-functional lung

Fetal Circualtion

Fetus

Week 9 → Week 40

Fetal lung → non func.

I- The oxygenated blood coming from the placenta:

رئة جنين

- Oxygenated blood is carried from placenta to the fetus via Lt umbilical vein which passes to liver.

Lt branch of Portal vein ox. blood Pulmonary [illegible] Resp.

- **In the liver:** most of it passes through the **ductus venosus** to reach the I.V.C.
- **The I.V.C.** opens into the Rt atrium.
- **In Rt atrium:** most of blood is directed, through foramen ovale, to Lt atrium as:

  Opening of I.V.C. faces foramen ovale.

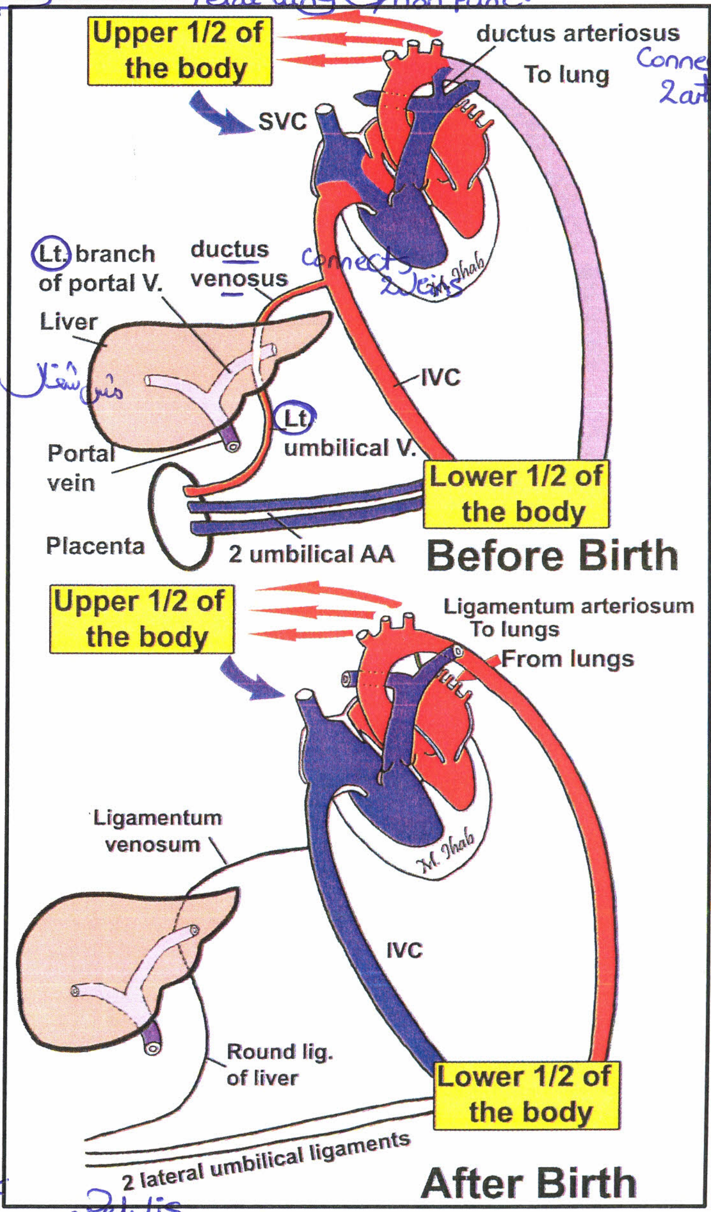
  Valve of the I.V.C. directs the blood towards foramen ovale.

- **From the Lt atrium:** the blood passes to the Lt ventricle then to the arch of aorta where it is distributed mainly to the heart, head and neck and upper limbs. → A. Aorta, الأماكن الحيوية (brain)

مش شغال

II- The deoxygenated blood:

- **Blood from the upper of ½ the body carried by the S.V.C:.** reaches the Rt atrium where it passes directly to the Rt. ventricle because:
  - * Opening of SVC faces the tricuspid orifice.
  - * Lower border of septum secundum prevents the blood from entering the foramen ovale.
- **On reaching Rt ventricle,** the deoxygenated blood passes to the pulmonary trunk. [illegible] lung مش شغالة
- **From the pulmonary trunk,** blood passes through the **ductus arteriosus** to reach the distal part of arch of aorta to the descending aorta and from it to the umbilical arteries and the placenta. (Mixing of blood) → lower half of body (Abdomen, Pelvis, LL)


Upper 1/2 of the body
ductus arteriosus
To lung
Connects 2arteries
SVC
Lt. branch of portal V.
ductus venosus
connects 2veins
Liver
IVC
Lt umbilical V.
Portal vein
Lower 1/2 of the body
Placenta
2 umbilical AA
Before Birth
Upper 1/2 of the body
Ligamentum arteriosum
To lungs
From lungs
Ligamentum venosum
IVC
Round lig. of liver
Lower 1/2 of the body
2 lateral umbilical ligaments
After Birth
M. Ihab

Circulation دوران تغير تنفس

Changes in circulation at birth

A) Immediate changes:

1) Establishment of pulmonary circulation:

Immediately after birth, respiration starts and lungs expand. الصرخة, X1

This leads to establishment of the pulmonary circulation.

2) Functional closure of the foramen ovale:

It occurs as a result of firm apposition of septum primum to septum secundum due to:

Pulmonary veins [illegible] lung [illegible]

- * Increased pressure inside Lt. atrium (due to establishment of the pulmonary circulation).
- * Decreased pressure inside the Rt. atrium (due to stoppage of the placental blood flow).

umbilical vein مقفل [illegible]

3) Functional closure of ductus arteriosus:

Ductus arteriosus becomes functionally closed immediately after birth by contraction of its muscular wall. عشان الدم هيفضل المنطقة اتوسع مفيش دم شيل

B) Late fibrotic changes: Permanent changes

1) Lt. umbilical vein: becomes the ligamentum teres of the liver. (Round ligament)

2) Ductus venosus: becomes the ligamentum venosum of the liver.
Joins Portal V + IVC

3) Ductus arteriosus: becomes the ligament arteriosus. um

4) Distal part of umbilical arteries: become the lateral umbilical ligaments. =medial

5) Permanent closure of foramen ovale.
المرة دي كيب بقى مش
Functional

Endocrine Glands

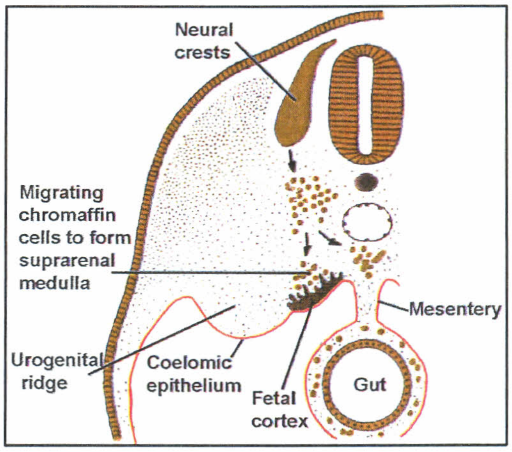
1- Development of suprarenal gland

The suprarenal cortex: is mesodermal in origin.

- During the 5th week, mesothelial cells of the coelomic epithelium on either side of the mesentery of the gut proliferate to form the fetal cortex.
- A second layer of cells develop from the coelomic mesothelium and surround the fetal cortex to form the permanent cortex.

The suprarenal medulla: is ectodermal in origin.

Chromaffin cells derived from the neural crest migrate to enter the medial aspect of the fetal cortex and form the suprarenal medulla.


Neural crests
Migrating chromaffin cells to form suprarenal medulla
Mesentery
Urogenital ridge
Coelomic epithelium
Fetal cortex
Gut

Fate:

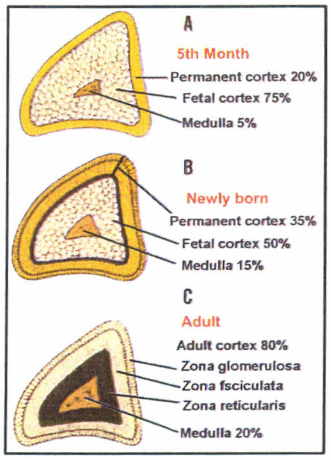
- The fetal cortex regresses rapidly except its outer layer which differentiated into zona reticularis.
- The permanent cortex differentiates into: zona glomerulosa and zona fasciculate.
- Zona glomerulosa and zona fasciculate are present at birth while zona reticularis not recognizable until the end of third year.

Congenital adrenal hyperplasia:

It is a genetic disorder associated with excess ACTH secretion by pituitary.

It leads to hypertrophy of suprarenal cortex and over production of androgens.

It results in pseudohermaphrodism in the female.


A
5th Month
Permanent cortex 20%
Fetal cortex 75%
Medulla 5%
B
Newly born
Permanent cortex 35%
Fetal cortex 50%
Medulla 15%
C
Adult
Adult cortex 80%
Zona glomerulosa
Zona fsciculata
Zona reticularis
Medulla 20%

2- Development of pituitary gland

Sources: the pituitary gland is derived from 2 ectodermal sources:

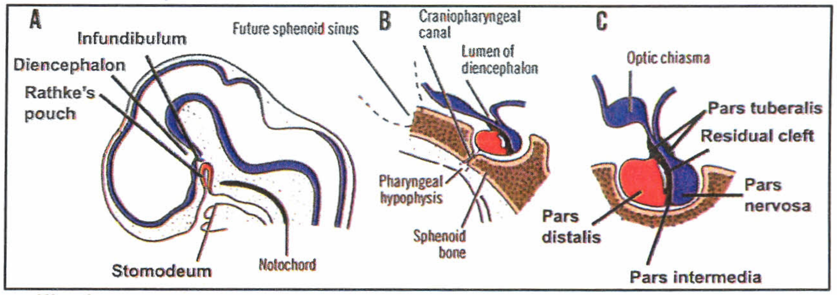
Anterior lobe: develops from the ectoderm of the roof of stomodeum.

Posterior lobe: develops from the floor of the diencephalon.

Development:

A) Rathke's pouch

- It is a diverticulum grows upwards from the ectoderm of the roof of stomodeum in front of the buccopharyngeal membrane to form the anterior lobe of pituitary gland.


A
Infundibulum
Diencephalon
Rathke's pouch
Stomodeum
Notochord
Future sphenoid sinus
B
Craniopharyngeal canal
Lumen of diencephalon
Pharyngeal hypophysis
Sphenoid bone
C
Optic chiasma
Pars tuberalis
Residual cleft
Pars nervosa
Pars distalis
Pars intermedia

The pouch comes in contact with the infundibulum.

The pouch loses its connection with stomodeum and is transformed into a closed vesicle.

The vesicle differentiates to form:

Pars distalis: is derived from the anterior wall of the vesicle.

Pars intermedia: is derived from the posterior wall of the vesicle.

Pars tuberalis: is an upward extension of the wall of vesicle.

The cavity of the vesicle finally forms a residual cleft.

B) Infundibulum

It is a diverticulum which projects from the floor of the diencephalon.

It grows downwards in the direction of Rathke's pouch to form posterior lobe of the pituitary gland.

The infundibulum differentiates into the pars nervosa (posterior lobe) and pituitary stalk.

Congenital anomaly: craniopharyngioma: It is a tumour formed from persistence of a small portion of Rathke's pouch in the roof of the pharynx.

Muscular System

Skeletal muscle is derived from paraxial mesoderm.

Cardiac muscle is derived from splanchnic mesoderm around the heart tube.

Smooth muscles are derived from splanchnic mesoderm around the gut.

From ectoderm → sweat gland & pupillary muscles.

Striated Skeletal musculature

- Somites and somitomeres form musculature of the axial skeleton, body wall, limbs and head.
- From occipital region caudally, the somites differentiate into 2 muscle-forming regions:
  * One appears at ventrolateral lip of the dermomyotome (hypomeric musculature).
  * The other lies at the dorsomedial lip of the dermomyotome (epimeric musculature).

Derivatives of precursor muscle cells

Epimeric musculature forms the muscles of the back.

Hypomeric musculature forms the muscles of the limbs and body wall:

- In cervical region: They form scalene, geniohyoid and prevertebral muscles.
- In thorax: They split into 3 muscle layers (external, internal & innermost intercostals).
- In abdomen: They split into 3 muscle layers (external, internal obliques & transversus abdominis).
- In lumbar region: They form quadratus lumborum.
- In sacral and coccygeal regions: They form diaphragm and striated muscles of the anus.

N.B.: A ventral longitudinal column arises at the ventral tip of the hypomeres.

This column is represented by:

- Rectus abdominis in abdomen.
- Infrahyoid muscles in neck.
- Sternalis muscle in thorax.

Head musculature

All voluntary muscles of the head are derived from paraxial mesoderm (somites & somitomeres). These muscles include muscles of the tongue, eye and those of pharyngeal arches.

Muscles of the iris are derived from optic cup ectoderm.

Limb musculature

The muscles of the limbs are derived from the somites which migrate into the limb bud.

With elongation of the limb buds, the muscle tissue splits into flexor and extensor components.

Septum transversum

The septum transversum is formed in the neck by fusion of the myotomes of the 3rd, 4th and 5th cervical segments and receives motor nerve supply from phrenic nerve.

With folding of the embryonic disc and descent of the heart, the septum transversum is pushed caudally to reach the lower part of the thoracic cavity.

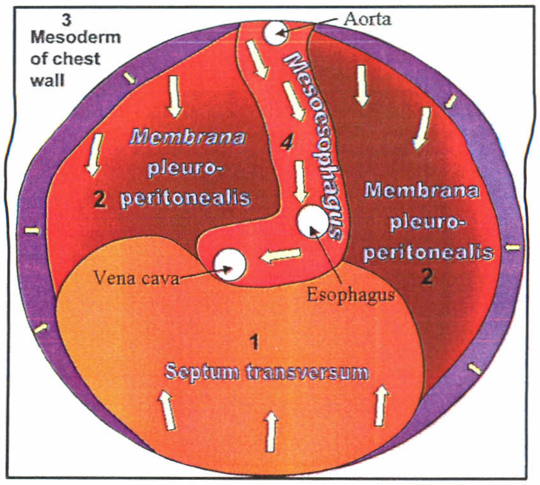
The septum transversum becomes differentiated into 3 regions:

- Caudal region (ventral mesogastrium): gives rise to lesser omentum, falciform, coronary & triangular ligaments.
- Central mesenchyme: gives rise to hematopoietic cells of the liver.
- Cranial region: gives rise to central tendon of diaphragm.

Development of the Diaphragm

The diaphragm is mesodermal in origin.

It is formed by union of the following mesodermal structures:


3
Mesoderm of chest wall
Aorta
Mesoesophagus
4
Membrana pleuro-peritonealis
2
Membrana pleuro-peritonealis
2
Vena cava
Esophagus
1
Septum transversum

1- Septum transversum:

- It is formed in neck and descends to the lower part of the thoracic cavity.
- It forms an *incomplete septum between thorax and* abdomen due to presence of pericardio- peritoneal canals postero-lateral to it.
- It forms central tendon of diaphragm.

2- The 2 pleuro-peritoneal membranes:

- They grow medially until finally close the pericardio-peritoneal canals.
- They form the dorsolateral parts of the diaphragm.

3- Mesoderm of the chest wall:

- It grows inwards forming the periphery of the diaphragm.

4- Mesentery of the esophagus & mesoderm around aorta:

- They form crura of the diaphragm.

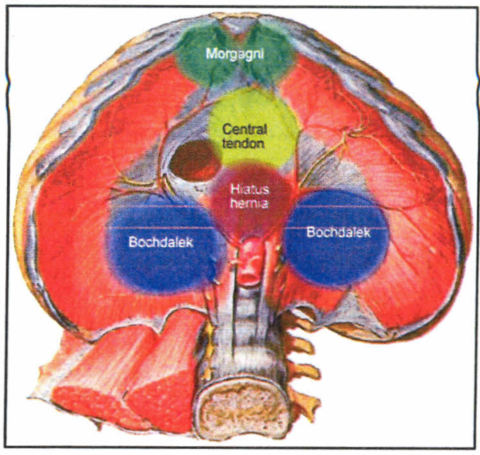
Congenital anomalies of the diaphragm

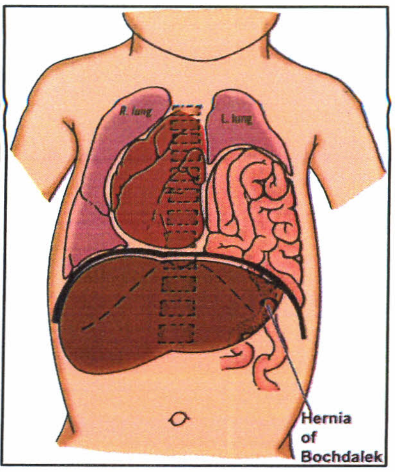
1- Parasternal hernia of Morgagni:

It is due failure of development of a small part of the *diaphragm between sternal* and costal parts.

2- Congenital hiatus hernia (esophageal hernia):

It is due to widening of the esophageal hiatus of the diaphragm and congenital shortening of the esophagus leading to protrusion of the stomach into the thorax.


Morgagni
Central tendon
Hiatus hernia
Bochdalek
Bochdalek


R. lung
L. lung
Hernia of Bochdalek

3- Congenital diaphragmatic hernia of Bockdalek:

It is due to failure of the pleuro-peritoneal membranes to close the pericardio-peritoneal canals.

The abdominal viscera enter the pleural cavity and compress the lung.

Development of the skull

The skull is formed of 2 parts

I- The neurocranium (forming the bony box containing the brain) is divided into:

A. Cartilaginous neurocranium:

On each side there are 4 pairs of cartilages:

1- Trabeculae cranii: form cribriform plate of ethmoid bone.

2- Hypophyseal cartilage: form the body of the sphenoid.

3- Parachordal cartilage: form basilar part of occipital bone.

4- Occipital sclerotomes: share in the formation of occipital bone.

More laterally there are 3 pairs of cartilages

1- Ala orbitalis: form the lesser wing of the sphenoid.

2- Ala temporalis: form the greater wing of the sphenoid.

3- Preotic capsule: form the petrous and mastoid parts of the temporal bones.

B. Membranous neurocranium:

It is derived from neural crest cells and paraxial mesoderm.

It gives rise to bones of skull cap which ossify in membrane.

II- The viscerocranium (forming the facial skeleton) is divided into:

A. Cartilagenous viscerocranium:

It is derived from first and second pharyngeal arches and gives rise to:

- The malleus and the incus (from 1st pharyngeal arch).
- The stapes and the styloid process (from 2nd pharyngeal arch).

B. Membranous viscerocranium:

It is derived from 1st pharyngeal arch and gives rise to:

- Maxilla, zygomatic, squamous part of temporal bone & mandible.

Congenital anomalies:

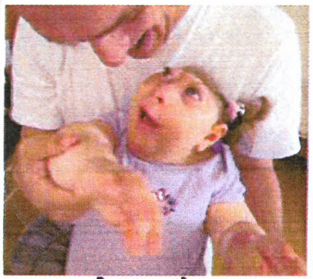
1- ***Acrania (cranioschisis):*** in which the vault of the skull fails to develop.

2- ***Craniosynostosis*** is due to the premature closure of one of the skull sutures:

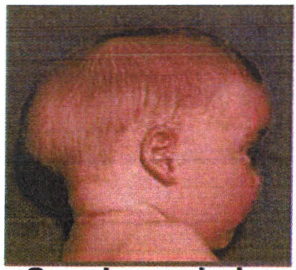
a- ***Scaphocephaly:*** in which the skull is elongated anteroposteriorly due to premature closure of the sagittal suture.

b- ***Oxycephaly (acrocephaly):*** in which the skull presents a tower like shape due to premature closure of the coronal suture.

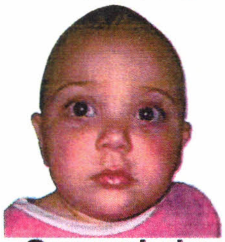
c- ***Brachycephaly:*** in which there is excess lateral growth of the skull due to the premature closure of coronal and lambdoid.



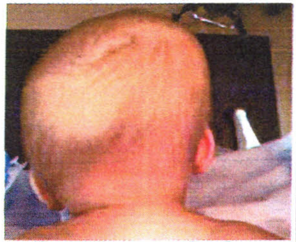
Acrania



Scaphocephaly



Oxycephaly



Brachycephaly

Development of the vertebral column

The vertebral column develops from the sclerotomes of the somites.

Formation of the centrum passes into four stages:

1. ***First stage:*** Is represented by the notochord.
2. ***Second stage:*** the notochord becomes surrounded by sclerotomes:
   - Each sclerotome is divided into upper and lower halves:
     - The upper ½ is less dense.
     - The lower ½ is dense.
   - The body of each vertebra is formed by upper ½ of one sclerotome and lower ½ of the previous one.
   - So the vertebrae are formed between the segments (intersegmental).
3. ***Third stage:*** mesenchymal bodies of the vertebrae are changed into cartilage.
4. ***Fourth stage:*** cartilaginous ossification occurs on the bodies of the vertebrae.

The sclerotomes at sides of the notochord fuse with each other forming centrum of the vertebra.

The centrum of the vertebra gives 3 processes:

1. **Dorsal process:** Forms the laminae and both dorsal processes are fused with each other to form dorsal arch and spine.
2. **Lateral process:** form the transverse process of the vertebra.
3. **Costal process:**
   - In the thoracic region: forms the rib.
   - In the cervical region: shares in formation of the transverse process.
   - In the lumbar region: forms transverse process.
   - In the sacral region: forms the anterior part of lateral mass of sacrum.

Development of Intervertebral Disc:

1. ***The nucleus pulposus*** is the remnants of the notochord.
2. ***The annulus fibrosus*** is derived from the sclerotomic mesenchyme.

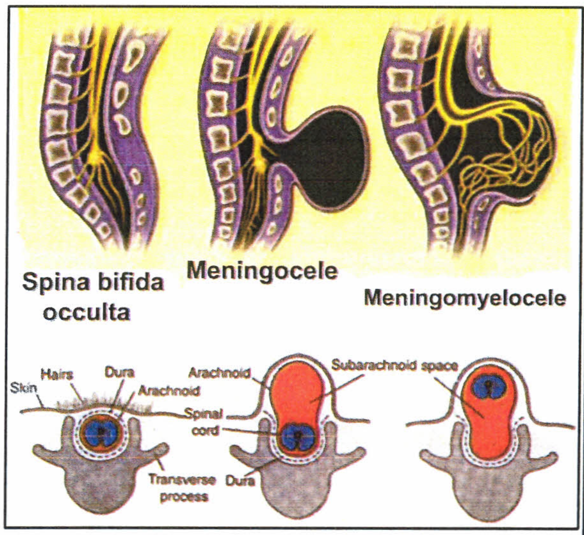
Congenital anomalies:

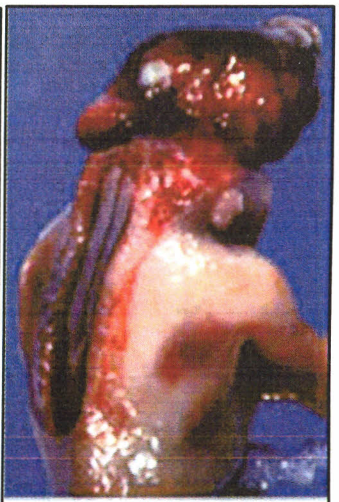
1- ***Spina bifida occulta:*** Is due to failure of fusion of the dorsal parts of one vertebra.

2- ***Meningocele:*** The meninges bulge through the defect.

3- ***Meningomyelocele:*** The meninges and spinal cord bulge through the defect.

4- ***Rachischisis:*** It is due to failure of closure of the neural tube




Rachischisis

Development of the limbs

The limb buds develops from the ventrolateral aspect of the body wall at the end of the 4th week.

The components of the limb bud:

1. An external ectodermal envelope is formed at the tip of the limb bud, where the ectoderm becomes thickened to form an Apical Ectodermal Ridge (A.E.R).

2. An internal mesenchymal core derived from the lateral plate mesoderm.

Mechanism of limb development:

At the distal part of the limb bud, the A.E.R. exerts an inductive influence on adjacent mesenchyme leading it to:

a) Proliferate rapidly to increase the length of the limb bud.

b) Remain as a population of undifferentiated cells.

At the proximal part of the limb bud, cells farther from the influence of the A.E.R begin to differentiate into cartilages, bones and muscles.

Differentiation of limbs:

- Changes in the limb bud: each bud presents 2 constrictions, which divide it into 3 segments:

Upper limb is now formed of arm, forearm and handplate.

Lower limb is now formed of thigh, leg and footplate.

- The limbs rotate in opposite directions:

The upper limb rotates 90° laterally so that the extensor muscles lie on the posterior surface and the thumb becomes lateral.

The lower limb rotates 90° medially so that the extensor muscles on the anterior surface and the big toe becomes medial.

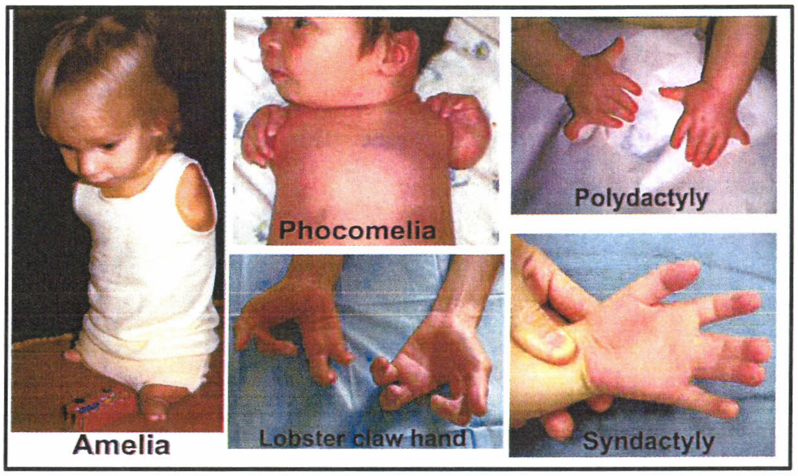
- Muscles of the limbs:

Muscles of the girdles develop from myotomes of somites.

The remaining muscles develop from the lateral plate mesoderm.

Congenital anomalies of limbs

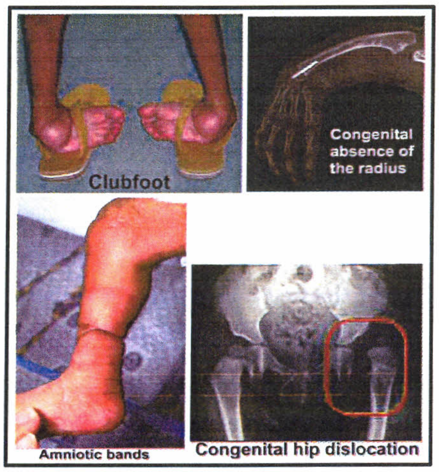
1. **Amelia:** complete failure of development of one limb.



2. **Phocomelia:** the hand or foot attached to the trunk.
3. **Polydactyly:** presence of an extra-finger.
4. **Syndactyly:** fusion of one or more fingers.
5. **Lobster claw hand:** consists of an abnormal cleft between the 2nd and 4th metacarpal bones.

The 3rd metacarpal and phalangeal bones are absent. The thumb and index finger & the fourth & fifth fingers may be fused.

6. **Clubfoot:** The sole of the foot is turned inward and the foot is adducted and plantar flexed.
7. **Congenital absence or deficiency of the radius.**
8. **Amniotic bands** may cause ring constrictions and amputations of the limbs or digits.



9. **Congenital hip dislocation** consists of underdevelopment of the acetabulum and head of the femur.

Skin

1- Epidermis

- It develops from the surface ectoderm.
- The melanoblasts migrate from the neural crest.

2- Dermis: It develops from two sources:

- Somatopleuric mesoderm which is the part of lateral plate mesoderm.
- Mesoderm of the dermatomes belonging to the somites.

3- Hair

- The hair follicles develop in the form of solid ectodermal buds which grow from the epidermis and sink into the 'underlying mesoderm.
- The lower end of the hair bud is swollen to form the hair bulb.
- This is then invaginated by a mass of mesoderm to form the hair papilla.
- Arrector pili muscle is mesodermal in origin come to be attached to the hair follicle.
- The hairs of the fetus are called lanugo hairs.
- At birth, the lanugo hairs degenerate and are replaced by the coarser adult hairs which develop from new hair follicles.

4- Skin glands:

- Sebaceous glands: they arise as side branches from the ectodermal buds of the hair follicles.
- Sweat glands: They arise from the surface ectoderm as solid down growths which later on canalize.

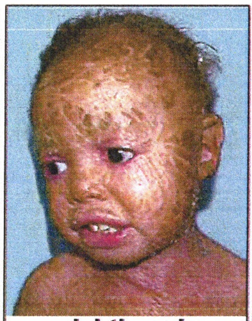
Congenital anomalies of skin

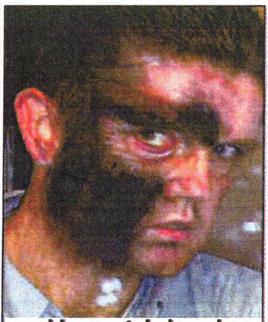
Ichthyosis: is excessive keratinization of skin.

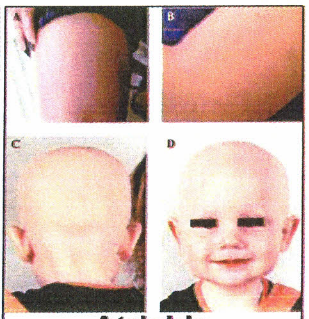
Congenital anomalies of hair

Hypertrichosis: is excessive formation of hairs.

Atrichia: is congenital absence of hair.


Ichthyosis


Hypertrichosis



Atrichia

Development of Mammary Gland

Mammary line:

The mammary gland develops from a line of ectodermal thickening in the epidermis called mammary or milk line.

This line extends on the ventral body wall from the axilla down to the medial part of the inguinal region.

The major part of this line disappears shortly after its appearance, leaving only a limited part in the thoracic region where the mammary gland develops.

Formation of the glandular tissue:

The mammary gland arises as 15-20 solid ectodermal buds from the mammary line.

These buds shift into the underlying mesoderm where they elongate and branch repeatedly.

The buds, then, become canalized shortly before birth to form the lactiferous tubules.

Each of these tubules forms a separate lobe of the gland.

The lactiferous tubules open into a pit (depression) on the surface.

Shortly after birth, this pit becomes everted and protrudes on the surface secondary to proliferation of the underlying mesoderm thus forming the nipple.

At puberty, the mammary gland enlarges in size under the influence of the ovarian hormones.

These hormones lead to new branching of the lactiferous tubules and to deposition of more fat between the lobules of the gland.

Anomalies of the mammary gland:

1- Polythelia (supernumerary nipple):

It is the presence of more than one nipple on one side, anywhere along the mammary line.

2- Polymastia:

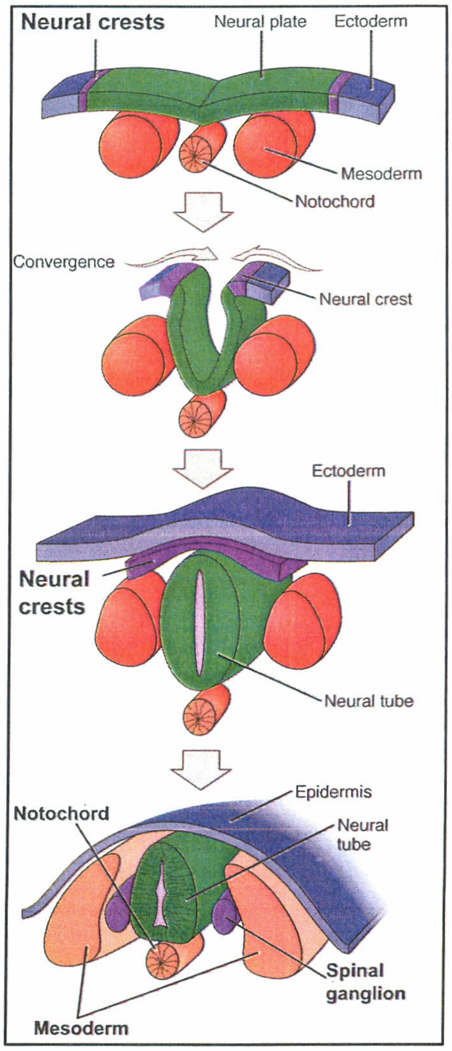
It is presence of an accessory whole gland developed from a rudiment of the mammary line.

3- Inverted nipple: is failure of the nipple to become everted.

Development of the Central Nervous System

C.N.S develops from neural tube which arises from the ectoderm:

- It appears in the 3rd week as a thickening of the ectoderm known as the neural plate extending from the buccopharyngeal membrane to primitive knot.
- The neural plate will from the neural groove which has 2 elevated edges called neural folds.
- The neural folds fuse together transforming the neural groove into neural tube lying beneath the ectoderm in the median plane.
- The surface ectoderm regains its continuity again.
- The fusion of the folds is absent at the anterior & posterior ends of the tube leaving 2 openings on the ectoderm called the anterior & posterior neuropores.
- Anterior neuropore closes at 23rd day while posterior neuropore closes at 25th day.
- The closed neural tube develops into the spinal cord & brain.



Neural Crests

Formation:

It arises as a strip of ectodermal cells situated along the lateral edge of the neural groove.

As the 2 edges of the neural groove fuse together forming the neural tube, the 2 ***neural crests*** separate as 2 longitudinal cords that migrate ventrally to lie one on each side of the neural tube.

Derivatives: see general embryology

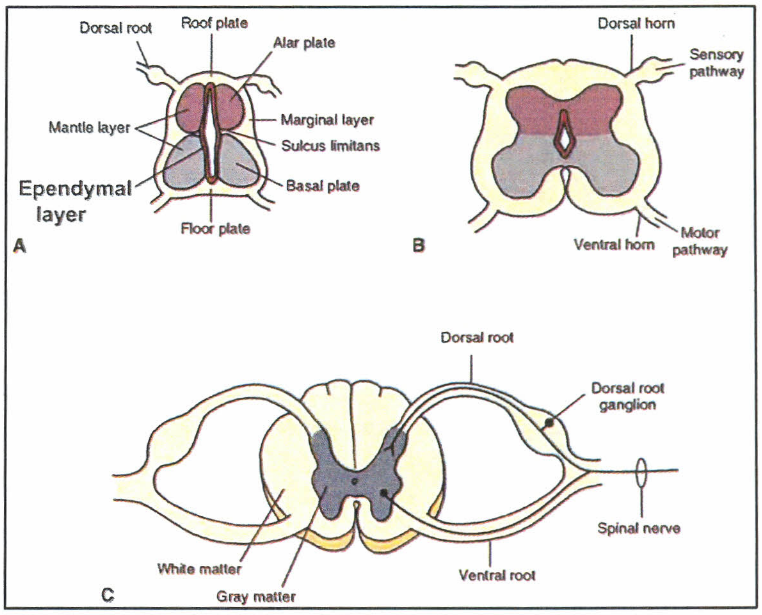
1. Ganglia: a- Sensory ganglia of 5th, 7th, 9th & 10th cranial nerves.
   b- Autonomic ganglia (sympathetic & parasympathetic).
   c- Preaortic ganglia.
   d- Dorsal root ganglia of spinal nerves.
2. Cells: Schwann, glial, melanoblasts & pigmented epithelium of iris.
3. Adrenal medulla, arachnoid and pia maters.
4. Some bones of the skull, dermis of the face & teeth enamel.
5. Septum between ascending aorta & pulmonary trunk.
6. Carotid body.

Development of the spinal cord

Development:

- The spinal cord develops from the caudal part of the neural tube.
- The neural tube is formed of one layer of columnar epithelium surrounding central canal.
- Then this layer proliferates, so the neural tube is formed of:
  a) 2 lateral thick walls.
  b) Thin roof and floor plates.

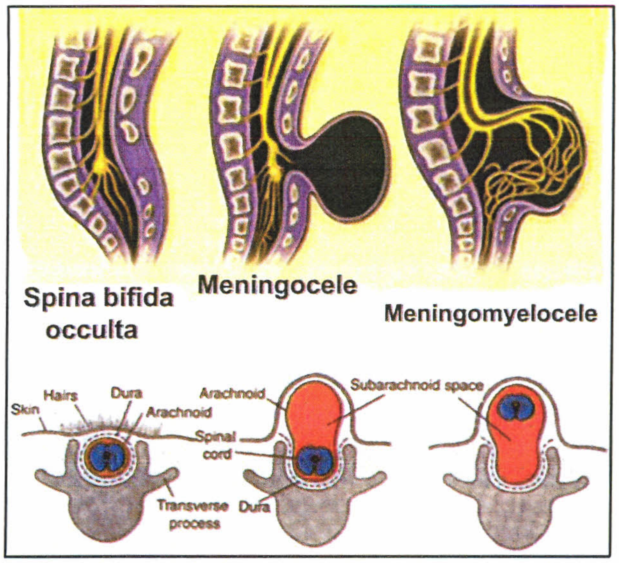
- The lateral wall differentiates into 3 layers:
  - * Inner ependymal layer: gives rise to:
    - a) Ependymal cells lining the spinal cord.
    - b) Neuroblast cells which migrate to the mantle layer.
  - * Middle mantle layer: formed of neuroblasts (nerve cells) and spongioblasts (neuroglial cells) which form the grey matter.
  - * Outer marginal layer: formed of nerve fibres which form the white matter.

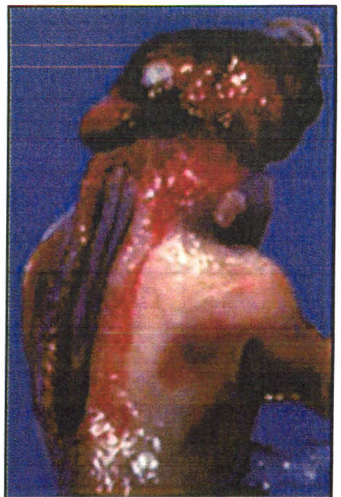

Dorsal root
Roof plate
Alar plate
Mantle layer
Marginal layer
Sulcus limitans
Ependymal layer
Basal plate
Floor plate
A
Dorsal horn
Sensory pathway
B
Ventral horn
Motor pathway
Dorsal root
Dorsal root ganglion
Spinal nerve
White matter
Ventral root
C
Gray matter

- A groove called sulcus limitans appears on the inner surface of the lateral wall on either side dividing it into:
  - * An alar plate: contains sensory cells and forms the posterior horn of the spinal cord.
  - * A basal plate: contains motor cells and forms the anterior horn of the spinal cord.
- The rate of growth of the spinal cord is slower than the vertebral canal:
  - * In the 3rd intra-uterine month: spinal cord occupies the whole length of the vertebral canal.
  - * At time of birth: the lower end of the spinal cord lies at the lower border of L3.
  - * In the adult: the lower end of the spinal cord lies at lower border of L1.
- The lumen of the canal becomes narrow and forms the central canal of the spinal cord.
- Myelination of the fibres in the spinal cord:
  - * Begins in the 4th month of the intrauterine life.
  - * Is completed by the end of 1st year.

Congenital anomalies:

1. **Spina bifida occulta:** Is due to failure of fusion of the dorsal parts of one vertebra.
2. **Meningocele:** The meninges bulge through the defect.
3. **Meningomyelocele:** The meninges and spinal cord bulge through the defect.
4. **Rachischisis:** is due to failure of closure of the neural tube.


Spina bifida occulta
Meningocele
Meningomyelocele
Hairs
Dura
Skin
Arachnoid
Arachnoid
Spinal cord
Transverse process
Dura
Subarachnoid space



Rachischisis